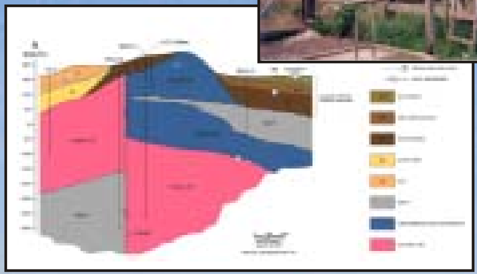
GROUNDWATER RESOURCES MONITORING REPORT AND MANAGEMENT PLAN

Limón de la Cerca, Republic of Honduras, C. A.



June 2002

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July 25, 2002

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Subject: Groundwater Resources Monitoring Report and Management Plan, Limón de la Cerca, Honduras, Contract No. 522-C-00-01-00287-00

Dear Ing. Cruz:

In accordance with the above referenced contract, Brown and Caldwell is pleased to forward two copies of the English version of the Groundwater Resources Monitoring Report and Management Plan for Limón de la Cerca, Honduras. The Spanish language version of this report is being submitted separately. Each report includes the electronic file of the report and the Water Resources Management System on two separate compact disks.

The submittal of this report and the reports for Utila, Choloma, Villanueva, and La Lima complete our work under this contract.

We appreciate the opportunity to have been of service to USAID. If you have any questions, please do not hesitate to give me a call at (925) 210-2278.

Sincerely,

BROWN AND CALDWELL

Jeffrey C. Nelson

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Project Director

JN:PS:ap
Enclosure

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF APPENDICES

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

bgs	below ground surface
ft	feet
GIS	geographic information system
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
in	inch
km	kilometer
lpcd	liters per capita per day
lps	liters per second
m	meter
mg/L	milligrams per liter
mgd	million gallons per day
mi	mile
mld	million liters per day
mm	millimeter
TDS	total dissolved solids
USAID	United States Agency for International Development
VOC	volatile organic chemicals
WHO	World Health Organization
WRMS	Water Resources Management System
ZIP	zoned industrial park

GLOSSARY OF TERMS

Alluvial: Pertaining to or composed of alluvium or deposited by a stream or running water.

Alluvium: A general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope.

Aquifer: A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.

Aquifer Test: A test involving the withdrawal of measured quantities of water from or addition of water to, a well and the measurement of resulting changes in head in the aquifer both during and after the period of discharge or addition.

Fault: A fracture in the continuity of a rock formation caused by a shifting or dislodging of the earth's crust, in which adjacent surfaces are displaced relative to one another and parallel to the plane of fracture.

Fracture Trace: Natural linear features less than 1.6 kilometers (1 mile) long that can be identified by aerial photographs.

Groundwater: The body of water that is retained in the saturated zone that tends to move by hydraulic gradient to lower levels.

Lithology: The study of rocks; primarily mineral composition.

Transmissivity: The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

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EXECUTIVE SUMMARY
Groundwater Resources Monitoring Report and Management Plan
Limón de la Cerca, Honduras
June 2002

The United States Agency for International Development (USAID) contracted Brown and Caldwell to perform groundwater monitoring studies for the Island of Utila and the municipalities of Villanueva, Choloma, La Lima, and Limón de la Cerca. This Groundwater Resources Monitoring Report and Management Plan presents the results of the groundwater monitoring study and includes a groundwater resources management plan to help ensure the sustainable management of the groundwater resources for Limón de la Cerca, Honduras.

Background

Limón de la Cerca, also known as "Ciudad Nueva" and "Juan Benito Guevara," is located approximately 5 kilometers (km) (3.1 miles (mi)) northeast of the municipality of Choluteca in the Department of Choluteca, along the PanAmerican Highway. USAID, along with various government and non-government organizations, has been constructing several resettlement colonias in this area. The purpose of these communities is to provide housing for families that were displaced due to the flooding caused by Hurricane Mitch in 1998. Limón de la Cerca has a planned capacity of 2,250 homes with an estimated population of 13,500. Currently, the community is approximately 50 percent developed.

Limón de la Cerca lies within the Choluteca River valley with the Choluteca River lying to the north and west. The relatively flat Choluteca valley extends for several kilometers to the north, east, and south, with the exception of a slight topographically high area interrupting the flat terrain roughly 1 km (0.6 mi) to the south. There is also a hill on the north side of Limón de la Cerca. This area receives between 1,500 and 1,900 millimeters (mm) (60 and 75 inches (in)) of precipitation per year.

Description of Existing Water System and Water Demands

Five municipal wells currently provide the municipal water supply for Limón de la Cerca. These wells pump into adjacent small elevated bladder tanks and to nearby distribution points with a combined capacity of 16 liters per second (lps) (250 gallons per minute (gpm)).

Residents obtain water by hand directly from community taps located near the elevated tanks. The construction of the distribution system, including a 946,000-liter (250,000-gallon) brick reservoir and connections to customers, is in the process of being completed. With the current collect and carry water system, it is estimated that average annual per capita water use is low, approximately 38 liters per capita per day (lpcd) (10 gallons per capita per day (gpcd)). Once the distribution system is complete, it is anticipated that per capita water use will increase to 151 lpcd (40 gpcd).

The current average annual demand is estimated to be 228,000 liters per day (lpd) (60,000 gallons per day (gpd)). Once the development is complete and houses are connected to the distribution system, average annual demand is expected to increase to 2,044,000 lpd (540,000 gpd) and water demand during the maximum day is expected to increase to 3,066,000 lpd (810,000 gpd). Assuming the wells operate a maximum of 20 hours per day, a total well capacity of 43 lps (675 gpm) will be required to meet maximum day demand. Additional well capacity of 28 lps (450 gpm) will be needed to provide maximum day supply upon completion of the water distribution system, with the installation of water service to each customer, and when the community has been fully developed.

Groundwater Resources Evaluation

The groundwater resources evaluation consisted of the collection of pertinent existing data, development of a preliminary conceptual hydrogeologic model, a field investigation program, and the development of a numeric groundwater flow model.

Brown and Caldwell developed a preliminary conceptual hydrogeologic model based on the concept that the fractured igneous rocks of the upland areas serve as the major source of groundwater recharge to the alluvium and bedrock in the Limón de la Cerca area.

The primary objective of the field investigation was to evaluate if significant sources of water exist in areas previously not evaluated that included the underlying bedrock near the recently constructed reservoir, and within the nearby Choluteca River Floodplain. The field investigation consisted of conducting a surface geophysical survey, installation and aquifer testing of three wells, a water quality survey, a reconnaissance of the area to evaluate the surface geologic, topographic and hydrogeologic features, and identifying potential sources of groundwater contamination.

Results of the field investigation indicate that marginal water supplies are present within the upper 152 meters (500 feet) of bedrock in the vicinity of the newly constructed water supply tank. Available data indicate that fracture flow in the igneous bedrock plays an important role in groundwater recharge. However, the presence of faults and discontinuous lithologic units may hinder recharge flow pathways. Results of this investigation also indicate that the alluvial deposits located on the southeast margins of the Rio Choluteca flood plain to the northeast do not yield sufficient supplies for municipal purposes. However, the localized fracture system in the vicinity of existing supply well LC-4, located just north of the PanAmerican Highway, has potential to yield water supplies capable of meeting future municipal needs.

Water quality surveys of the existing wells and test wells found that the groundwater quality meets the World Health Organization guidelines for drinking water quality. Exceptions are that concentrations of coliform were detected in two of the existing water supply wells and two of the wells drilled by Brown and Caldwell, indicating possible bacteriological contamination of the groundwater.

Water Resources Management System

Brown and Caldwell developed a Water Resources Management System to store, manage, and analyze water resource related data gathered and generated for this project. This desktop computer application is a management tool that can be used by the municipality and other decision-makers to sustainably manage the groundwater resources. The system is composed of both a data management system and a geographic information system linked together as one application.

Recommended Groundwater Resources Management Plan

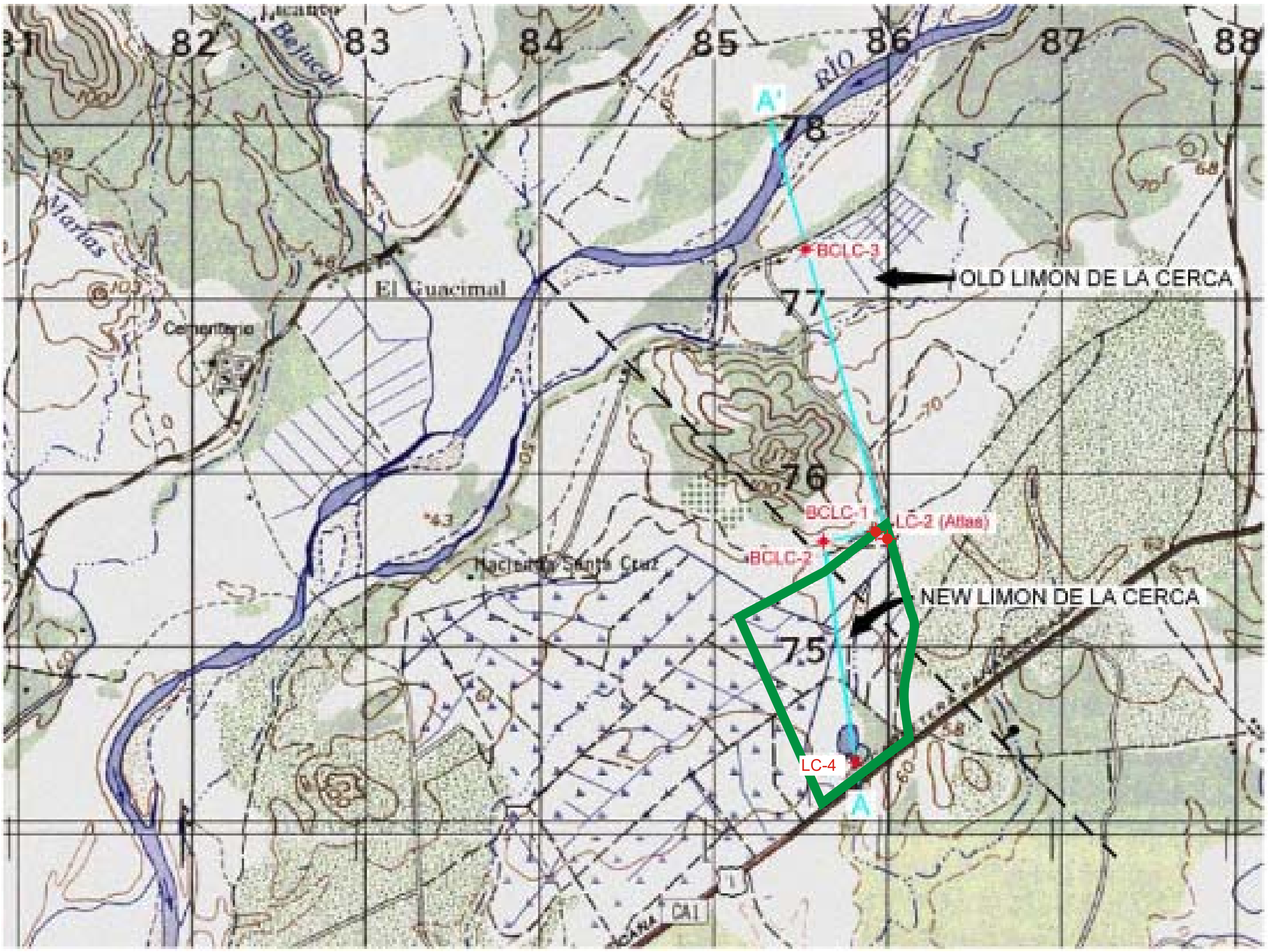
Figure ES-1 presents a groundwater resources map that depicts the locations of the existing wells, test wells, and other key information. The following recommendations are made regarding the management of Limón de la Cerca's groundwater resources:

1. Increase total water supply capacity to 43 lps (675 gpm) from the existing 16 lps (253 gpm) well supply. Redrill existing well LC-4 and install a new well southwest of well LC-4. If these two wells and the other exisiting wells do not provide a total capacity of 43 lps (675 gpm), install an additional well northeast of well LC-4.

2. Conduct a regular groundwater monitoring program consisting of monitoring groundwater levels, groundwater useage, and water quality in selected wells.

3. Establish a wellhead protection program to reduce the chance of groundwater contamination impacting water supply wells.

4. Ensure a functioning water utility that is financially self-sufficient by:
    a. developing a customer inventory;
    b. developing a financial plan and charge customers for water useage;
    c. having a governance structure and appropriate staff;
    d. addressing water loss from the distribution system; and
    e. investigating potential sources for grants and loans.



EXPLANATION

- BCLC-1 WELL LOCATION
- A——A' CROSS-SECTION LOCATION
- FAULTLINE
- LIMON DE LA CERCA URBAN AREA

BROWN AND CALDWELL	DATE 6-10-02	SITE Limón de la Cerca, Republic of Honduras	FIGURE ES-1
	PROJECT 21143	TITLE Groundwater Resources Planning Map	

1.0 INTRODUCTION

The United States Agency for International Development (USAID) retained Brown and Caldwell to provide architecture and engineering services as part of the Honduras Hurricane Reconstruction Program to assure the sustainability of permanent repairs and expansions of selected water supply systems damaged by Hurricane Mitch. Specifically, this project consists of performing groundwater monitoring studies for the Island of Utila, the Sula Valley (La Lima, Villanueva, and Choloma), and the resettlement community of Nueva Limón de la Cerca near Choluteca.

This Groundwater Resources Monitoring Report and Management Plan (Report) presents the results of the groundwater monitoring study and includes a groundwater resource management plan to help ensure the sustainable management of the groundwater resources of Limón de la Cerca, Honduras.

This chapter provides a description of the project objectives, scope of work, and the report organization.

1.1 Project History and Objectives

Limón de la Cerca is located in the southern portion of Honduras as depicted in Figure 1-1. Limón de la Cerca depends exclusively on groundwater as its primary source of municipal water supply. It is anticipated that reliance on groundwater for the municipal water supply will increase as the population growth continues in the future. This project was initiated by USAID due to the increasing population in Limón de la Cerca, the need to quantify the available groundwater resources for sustainable development in this area, and the need to develop the groundwater resources while avoiding damage due to contamination and floods.

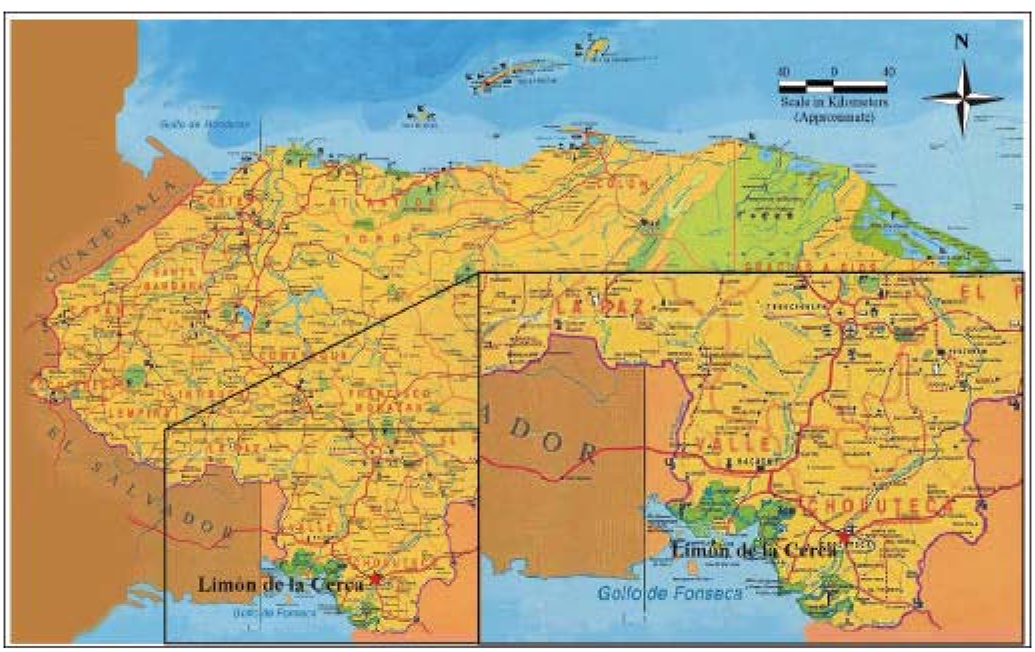


Figure 1-1. Site Location

As a result of the excessive precipitation produced by Hurricane Mitch, the Choluteca River flooded many villages along the river. Among the flooded communities was the Old Limón de la Cerca community, which has since been relocated 0.3 kilometers (km) (0.2 miles (mi)) west of its former location. To resettle additional people displaced by Hurricane Mitch, USAID has funded the construction of Nueva Limón de la Cerca, which is referred to as Limón de la Cerca in this report. The community of Limón de la Cerca is located south of the resettled community of Old Limón de la Cerca.

This project is an important element in meeting overall USAID objectives in Honduras. The two objectives that are addressed best by this project are the sustainable improvements in family health and more responsive and effective municipal governments, as described below (USAID, March 2000).

Sustainable improvements in family health. One of this objective's desired results is the rehabilitation of water system facilities, given that access to potable water reduces child diarrheal deaths, especially in rural areas. The USAID performance indicator for this result is the percentage of rural water systems operating at the "A" level. This is defined as a system where a) water is disinfected, b) there is a water board that meets at least every three months, c) there is a water fee paid by users, d) there is a maintenance employee, and e) water is available from the system on a daily basis.

More responsive and effective municipal government services. This objective includes a desired result of increased coverage of public services, including potable water supply, as measured by the percent of inhabitants receiving public utility services.

To help meet the above objectives, this project evaluated the sustainable yield of the groundwater resources in the Limón de la Cerca area and developed a groundwater resources management plan to help ensure a sustainable municipal water supply for Limón de la Cerca. Key components of the project include the following:

- identification of groundwater resources available to provide residents with a safe and sustainable water supply;
- development of a groundwater resource management plan and related tools that can be implemented and maintained by the municipality and its staff;
- training of local individuals in groundwater monitoring techniques, data collection, and database management for sustainable management of the groundwater resource; and
- project completion meetings with municipalities to discuss study results, present reports, and describe recommendations, to help ensure sustainable water supplies.

1.2 Contract and Scope of Work

This study was conducted by Brown and Caldwell for USAID under contract No. 522-C-00-01-00287-00, dated March 21, 2001. The scope of work for this project defines five phases under which to conduct the study. These five phases are described in this section.

Phase I – Analysis of Existing Information/Development of Conceptual Hydrogeological Model. This phase consisted of establishing consensus on the projects goals and objectives, data collection, preliminary conceptual hydrogeologic model development, and the identification of additional data needs.

Phase II – Field Investigation. This phase consisted of well drilling, aquifer testing, and water quality monitoring to fill data gaps and help provide data for refining the preliminary conceptual model. In addition, training was provided to local personnel in groundwater monitoring techniques.

Phase III – Hydrogeologic Modeling and Analysis. This phase consisted of refining the conceptual hydrogeologic model through quantitative groundwater modeling and analysis and development of estimates of the long-term sustainable yield of water resources in the study area.

Phase IV - Database and Training in Monitoring and Database Management. This phase consisted of groundwater database development and database training of local municipal staff and preparation of training manuals for both the database and monitoring methods. The database is named the Water Resources Management System. The training manuals are included as appendices E and F. This phase was executed concurrently with the other four phases.

Phase V – Final Report. This phase consisted of the development of a final project report that summarizes project data, activities, study results, and recommendations for sustainable management of the water resource in the area. The development of a groundwater resource management plan that includes appropriate measures for the development of the groundwater resources was also completed under this phase. This report represents the Phase V work product for the Limón de la Cerca urban area.

1.3 Report Organization

This report is organized into six chapters and associated appendices. The contents of each of the remaining chapters is briefly described below:

Chapter 2 – Background: This chapter provides a description of the community, climate, geology and soils, hydrogeology, wastewater management, and the regulatory setting.

Chapter 3 - Existing Water System and Water Demands: This chapter describes the existing water system and summarizes the historical demographics and projects future population and water use.

Chapter 4 - Groundwater Resources Evaluation: This chapter summarizes the methods, procedures, and results of the field investigation program. This chapter also presents a conceptual hydrogeologic model and a numeric groundwater model, recommends and numerically simulates well fields, and identifies potential sources of contamination to the groundwater resource. The training conducted on groundwater monitoring techniques is described in Appendix H.

Chapter 5 - Water Resources Management System: This chapter provides an overview of the water resource database and management tool developed for Limón de la Cerca and presents instructions for using this tool to assist in the management of Limón de la Cerca's water resource. The training conducted on the use of the database is described in Appendix H.

Chapter 6 – Conclusions and Recommendations: This chapter presents the conclusions and groundwater resources management recommendations. This chapter also describes the scope for recommended additional studies, if needed. Finally, this chapter presents a recommended groundwater resource management plan and includes policy and institutional recommendations for sustainable management of the resource.

2.0 BACKGROUND

This chapter presents a description of the community, climate, geology and soils, hydrogeology, land use, wastewater management, and regulatory setting for Limón de la Cerca.

2.1 Description of Community

Limón de la Cerca, also known as "Ciudad Nueva" and "Juan Benito Guevara," is located about 5 km (3.1 mi) northeast of the municipality of Choluteca in the Department of Choluteca, just north of the PanAmerican Highway. Limón de la Cerca is also the historical name of a small village that existed along the Choluteca River and has since been relocated approximately 0.3 km (0.2 mi) to the west of it's former location. The subject of this study is the new resettlement community of Limón de la Cerca that has been developed over the last three years with USAID funding (Figure 2-1).

Various government and non-governmental organizations have been constructing several resettlement communities in this area, including Limón de la Cerca. The purpose of these communities is to provide resettlement housing for families that lost their dwellings due to the flooding caused by Hurricane Mitch in October 1998.

Figure 2-1. View of Limón de la Cerca looking South from the Reservoir Site

Currently, 2,250 homes are planned for Limón de la Cerca, with a corresponding estimated final population of 12,500. The Limón de la Cerca community includes a vocational/technical school and medical clinic. The vocational/technical school is currently near completion. Limón de la Cerca consists of ten colonias that are described in Chapter 3.

Located south of Limón de la Cerca and just south of the PanAmerican Highway are the colonias of Satelite, Gracias a Cristo, and Marcelino Champagnat. Marcelino Champagnat has a planned capacity for 620 homes. Currently about 400 homes exist. Gracia a Cristo is planned for 156 dwellings. Satelite contains only 35 dwellings. The average estimated household size is seven persons per dwelling unit. Several other colonias are located further away. While none of these colonias are fully developed at this time, they are developing rapidly. This study only addresses Limón de la Cerca.

2.2 Climate

The climate of the Choluteca area is considered sub-tropical, with abundant rainfall during the wet season, followed by a very arid dry season. Choluteca receives between 2,000 and 2,050 millimeters (mm) (78.7 and 80.7 inches (in)) of precipitation per year, with nearly 80 percent of the rainfall occurring from September through December. Due to the project's short time frame and availability of historical precipitation data, Brown and Caldwell did not collect any supplemental rainfall data. Northeasterly winds prevail most of the year, but strong winds at times reverse this condition, especially during February and March. Average monthly temperatures range from 20.5°C to 36.1°C with an average relative humidity of 62 percent (SANAA, 1977).

2.3 Geology and Soils

Limón de la Cerca lies within the wide valley flood plain of the Choluteca River. The river is located to the north and west of the community. The valley is bound to the north and southwest by rugged upland areas comprised of a variety of igneous rocks. The valley terrain is relatively flat, interrupted only by occasional low remnant hills of volcanic or other bedrock material. The floodplain is bordered by terraces of Quaternary alluvial/fluvial deposits, which have been divided into upper, middle, and lower units based on sediment type and age. The upper terrace is comprised of mud flow and alluvial deposits derived from surrounding upland areas. The middle terraces, of limited extent, are situated along the margins of the Choluteca River flood plain. These deposits are suspected to be fluvial in nature and were most likely deposited by the Choluteca River. The lower terrace deposits represent current Holocene fluvial deposits and are situated within the river floodplain. Total thickness of the alluvial deposits is approximately 12.2 to 25.9 meters (m) (40 to 85 feet (ft)), and is reportedly underlain by volcanic rocks. Regional and local faults are documented in the Choluteca Valley. Part of a regional strike-slip fault system is located approximately 1 km (0.6 mi) to the north of the Choluteca River. This fault system trends northeast-southwest and can be traced across the southeast portion of Honduras. Other faults that trend northwest-southeast have been observed in the valley. Figure 2-2 presents a geologic map of the Choluteca area.

Historically, Honduras and most of Central America are situated in an area characterized by significant volcanic activity and structural deformation as a result of plate tectonics. From the coastline of El Salvador, to about 150 km (93.2 mi) inland, along the southern border of Honduras, the terrain represents the volcanic arc of the Cocos Plate subduction zone (Rogers, 2000). During the late Tertiary, plate subduction produced significant volcanic activity in the western and southern portion of Honduras, resulting in thick (up to 2 km (1.2 mi) in some areas) deposits of ignimbrites and pyroclastics (as those of the uplands north and south of Limón de la Cerca). Continued uplift in this area caused rivers to downcut rapidly, creating meander channels into the bedrock (UTIG, 2001). The strike-slip fault located north of Choluteca is believed to be related to the extensive Guayape strike-slip fault system located to the northeast, and may have controlled the location of the Choluteca River.

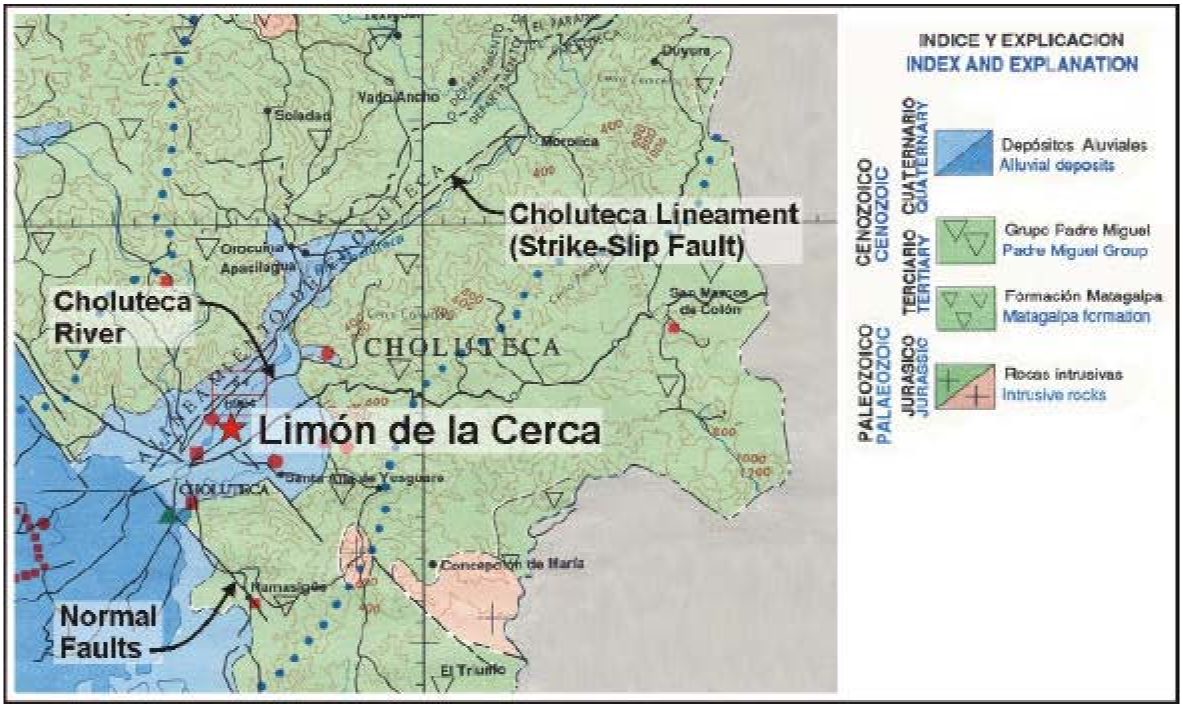


Figure 2-2. Geologic Map of the Choluteca Area

2.4 Hydrogeology

As previously mentioned, the Choluteca Valley is bounded to the north and southwest by rugged upland areas primarily comprised of igneous rocks. These upland areas serve as major surface and groundwater recharge areas for the Choluteca Valley. Surface water infiltrates into the fracture networks of the igneous rocks, providing groundwater recharge to the valley alluvium and bedrock. Groundwater from the northern uplands generally flows to the south and groundwater from the southern upland areas generally flows to the northwest. Once the groundwater from the upland areas enters the valley, alluvium and bedrock flow will generally begin to move down the valley toward the Choluteca and Sampile rivers. Both of these rivers are major groundwater discharge areas for the valley hydrologic system.

Within the valley, groundwater occurs in the bedrock and alluvium. Based on existing well information, saturated zones within the upper terrace deposits are limited in nature and do not produce sufficient supplies of groundwater. Currently, two wells are screened within alluvial material to a depth of 9.1 m and 21.3 m (30 ft and 70 ft) at Limón de la Cerca (LC-1 and LC-3, respectively). Each of these wells produces less than 227 liters per minute (lpm) (60 gallons per minute (gpm)). This seems to be a consistent trend observed throughout the upper terrace deposits in the vicinity of Limón de la Cerca based on the available existing well information.

The middle and lower terrace deposits are associated with more recent deposition by the Choluteca and Sampile rivers. These deposits are suspected to be limited in aerial extent, however, compared to the upper terrace deposits, they may have greater potential as a groundwater resource in localized areas.

Currently, two wells producing water from bedrock are serving Limón de la Cerca (LC-2 and LC-4). Production well LC-4 is located in the southern portion of the community and is screened to a depth of 65 m below ground surface (bgs) (200 ft bgs). Well LC-4 reportedly produces 946 lpm (250 gpm), with estimated yields in excess of 1,136 lpm (300 gpm). It is not clear how much of this production is attributed to bedrock. The second well, LC-2, is located in the northeast portion of Limón de la Cerca. This well is screened to a depth of approximately 40 m (125 ft) and produces approximately 189 lpm (50 gpm). A fifth well, Iglesia de Cristo (Luis) of unknown depth, is located approximately 100 m (328 ft) southwest of LC-2.

2.5 Wastewater Management

Historically, all of the homes in Limón de la Cerca have used outdoor latrines for sanitary needs. A central wastewater gravity collection system, comprised of 203 mm (8 in) diameter polyvinyl chloride (PVC) pipe, has recently been constructed within the colonias. The collection system will be connected to a wastewater interceptor along the PanAmerican Highway, which will eventually be connected to the Choluteca system for treatment and disposal. Eventually, all the homes within Limón de la Cerca will be connected to the system. Until then, the community will continue to rely on outdoor latrines.

2.6 Regulatory Setting

Servicio Autonomo Nacional de Acueductos y Alcantarillados (SANAA) is an autonomous Honduran governmental entity that operates the urban water and waste water systems for Tegucigalpa and 15 other municipalities. Technical support for the Limón de la Cerca water system is provided by Division Municipal de Servicios Basicos (DIMUSEB), of the Municipality of Choluteca.

The water systems in Honduras are regulated by the Honduran Ministry of Health. The drinking water standards are equivalent to standards defined by the World Health Organization (WHO). Currently, drinking water standards are not enforced and water compliance monitoring and reporting are not required in Honduras.

The Panamerican Health Organization (PAHO) provides technical support to municipalities through the Ministry of Health for water issues. Some other organizations have been formed in Central America recently to share experiences in water and sanitation management with municipalities.

3.0 DESCRIPTION OF EXISTING WATER SYSTEM AND WATER DEMANDS

This chapter describes the existing water supply system and municipal water demands in Limón de la Cerca. The information was obtained from reports prepared by others, discussions with municipal representatives, and our field reconnaissance.

3.1 Existing Water System

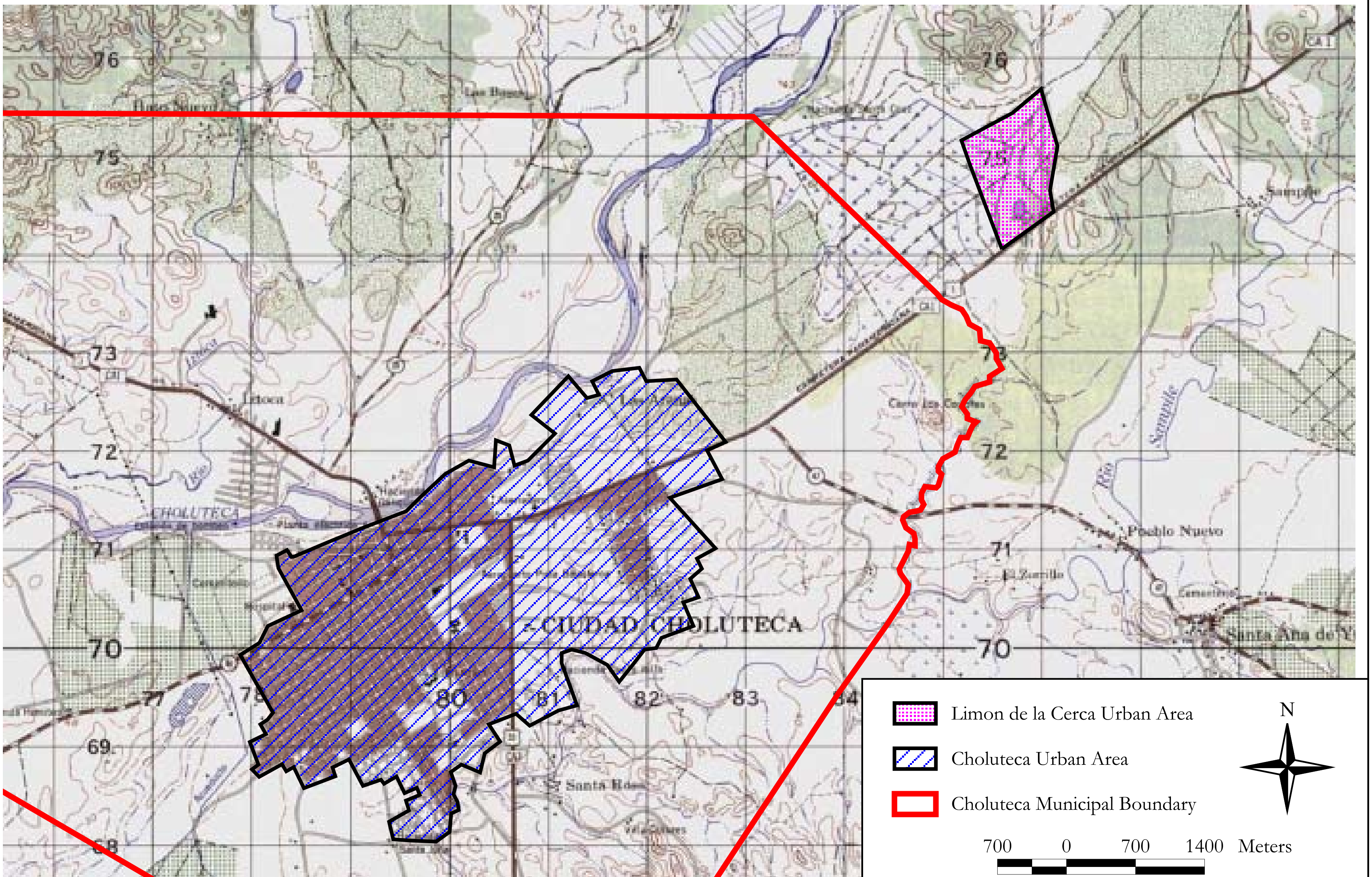
USAID funded the design of a water supply system that would provide potable water to the Limón de la Cerca resettlement community (CH2MHill, 2001). The water system is owned and operated by the community. The Municipality of Choluteca through its technical office DIMUSEB gives technical advice about operating and maintaining the system. The water supply system, as currently designed, includes:

- five temporary water supply wells with a temporary supply system that includes individual reservoirs and nearby community taps;
- a recently completed 950,000-liter (l) (250,000-gallon (gal)) brick reservoir located on a hill just north of the community that will supply water via gravity to the entire community;
- a distribution network consisting of 38 mm to 150 mm (1½-in to 6-in) diameter PVC pipe;
- a distribution main line from the reservoir connecting to a water distribution network;
- connections from the distribution network to existing houses and vacant lots;
- four future permanent water supply wells; and
- a water supply main and network from the proposed wells to the reservoir.

Currently, the five temporary water supply wells and the reservoir are the only components of the system where construction has been completed. Residents obtain water directly from the elevated plastic reservoirs located at each temporary well, or from nearby community taps.

The construction of the distribution main line, distribution network, and connections to houses and vacant lots is in the process of being completed. Construction of the water supply main line is scheduled for construction in the summer of 2002. Water will be pumped directly from the wells to the reservoir. The system will not contain any booster pump stations. Users will be supplied water via gravity from the reservoir. It is anticipated that groundwater will be the only source of water for the system.

3.1.1 Service Area and History. The community of Limón de la Cerca is located about 5 km (3.1 mi) northeast of the Municipality of Choluteca, just outside of the municipal boundary as seen in Figure 3-1. The community was created in 1999 to provide housing to people and families displaced by the flooding resulting from Hurricane Mitch. Approximately 2,250 dwellings are planned for the new Limón de la Cerca development, with approximately half of the planned dwellings currently built.



BROWN AND CALDWELL	DATE 1/28/2002	SITE Limon de la Cerca, Honduras, C.A.
	PROJECT 21143	TITLE Urban and Municipal Boundaries

FIGURE 3-1

Currently, there are ten colonias that comprise the Limón de la Cerca development. The significant development characteristics of these ten colonias are summarized in Table 3-1 and the locations are shown on Figure 3-2. Potable water is currently supplied by five temporary wells, as described below. The completion of the planned water supply system is scheduled for December 2002.

Table 3-1. Buildout Characteristics of Limón de la Cerca Colonias

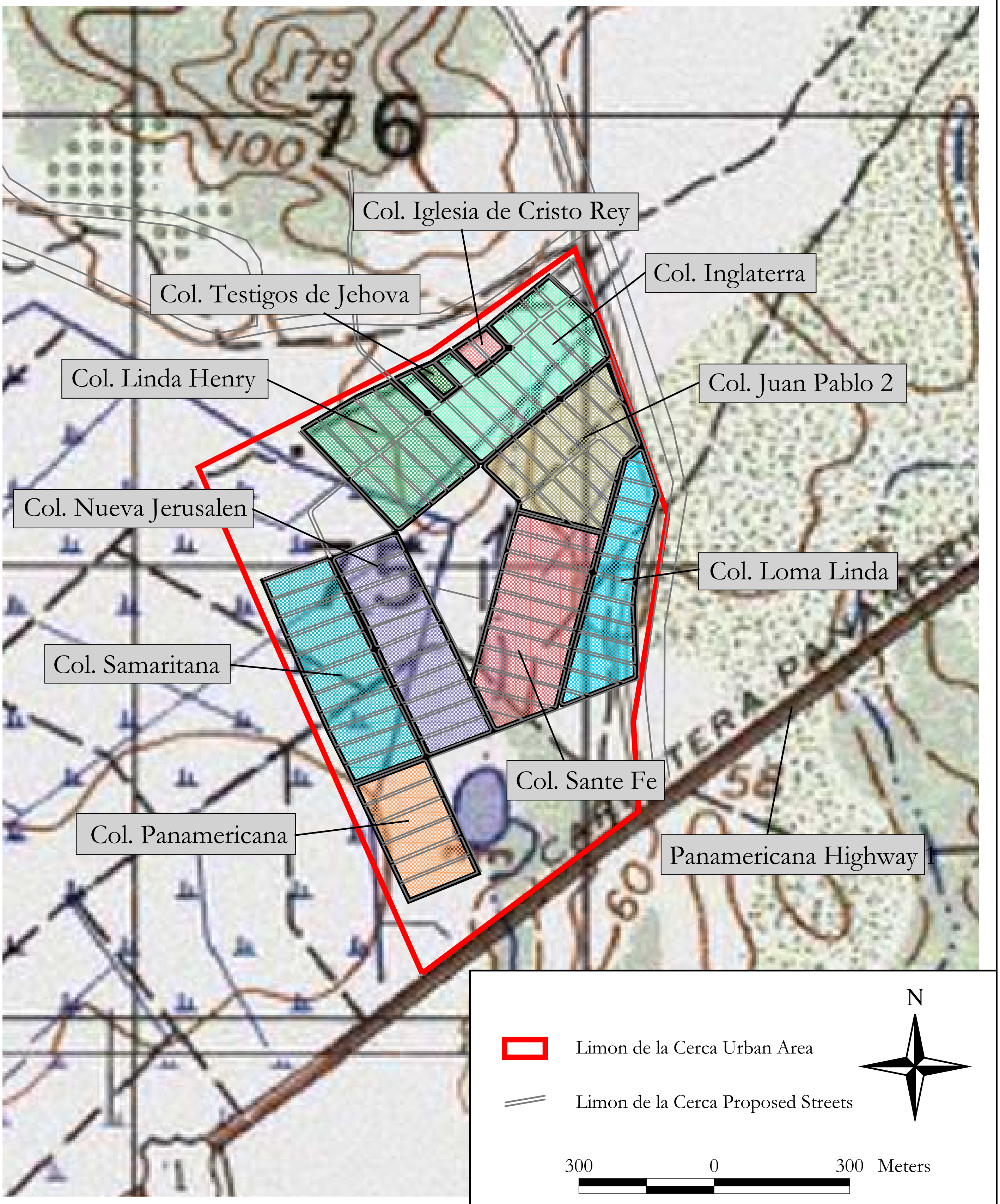
Colonia	No. of Homes	Area		Population
		hectare	acre	
Panamericana	210	5.61	13.9	1,260
Samaritana	330	8.76	21.6	1,980
Nueva Jersulén	308	8.24	20.4	1,848
Santa Fe	370	9.46	23.4	2,220
Juan Pablo II	265	7.87	19.4	1,590
Inglaterra	257	6.00	14.8	1,542
Loma Linda	183	5.29	13.1	1,098
Linda Henry	254	7.19	17.8	1,524
Testigos de Jehová	23	1.20	3.0	138
Iglesia de Cristo	50	2.72	6.7	300
Total	2,250	62.4	154.1	13,500

Note: Number of homes and population are approximated.

3.1.2 Water Supply Wells. Groundwater is the only source of water supply for Limón de la Cerca. Currently, there is no regular treatment or disinfection of the water prior to distribution. The only private water well is a hand-dug well, known as the Luis Well, that does not provide a significant amount of water. This private well is 15 m (49 ft) deep and located in Colonia Inglaterra.

Five municipal wells provide water for Limón de la Cerca. The locations of the wells are shown on Figure 3-3. At the time this report was prepared, the wells pumped directly into elevated plastic storage tanks adjacent to each well and to temporary distribution points near each well. The small plastic tanks and distribution points serve as a temporary source of water for residents. Residents collect and carry water back to their homes. Eventually, it is planned that all residences in Limón de la Cerca will be connected to the distribution system. Water service boxes are being placed at each residence and vacant lots in anticipation of a future water distribution system providing water service to each residence.

Each of the five drilled wells serving Limón de la Cerca are constructed in a similar manner (Figure 3-4). Information about each of the wells is presented in Table 3-2. Each well system consists of a submersible pump, PVC pipe column, and a concrete block that supports the assembly. Water is discharged through a galvanized steel line and fills an elevated plastic bladder tank, which serves as storage and a method to reduce pump cycling. The pumps are operated manually by members within the community. In general, the cost of electricity limits pump operation to a few hours a day. The wells are between an elevation of 24.4 m and 30.5 m (80 ft and 100 ft) above sea level. Electrical power to the wells is typically three phase, 240 volt.



BROWN AND CALDWELL

DATE	SITE	
1/28/2002	Limon de la Cerca, Honduras, C.A.	FIGURE 3-2
PROJECT	TITLE	
21143	Limon de la Cerca Colonias	

S Water Supply Production Well
T Production Wells proposed by others (not this study)
S 250,000-Gallon Brick Water Storage Tank
Pipeline 4-inches and larger
Pipeline 3-inches and smaller
Limon de la Cerca Street
Limon de la Cerca Boundary Line

N

300 0 300 Meters

BROWN AND CALDWELL	DATE 1/28/2002	SITE Limon de la Cerca, Honduras, C.A.	FIGURE 3-3
	PROJECT 21143	TITLE Existing Water Distribution System	

Figure 3-4. View of Municipal Wells LC-2, LC-3, and LC-4

Table 3-2. Well Characteristics

Well	Depth, diameter	Pump, HP	Capacity		Storage	
			lpm	gpm	liters	gallons
Ricardo Soriano LC1	200 ft 6-in PVC	3	117	31	15,142	4,000
Atlas LC2	Unknown 6-in PVC	Unknown	132	35	37,854	10,000
Bolsa Samaritana LC3	125' 6-in PVC	3	132	35	1,893	500
Panamericana LC4 (Pozo B)	120 feet 8-in PVC	7.5	443	117	None	None
Iglesia Cristo Rey	Unknown 6-in PVC	16	132	35	7,571	2,000
Total			956	253	62,460	16,500

PVC = polyvinyl chloride
gal = gallon
gpm = gallons per minute
HP = horsepower
liters = liters
lpm = liters per minute
Ref: CH2MHill, 2001

Plans by others call for the installation of up to four additional water supply wells, referred to as Wells or Pozos A and C through E; current well LC-4 is also referred to as Pozo B (CH2MHill, 2001). These wells are intended to replace the current wells and will supply water to the new reservoir. The well locations proposed by others are shown on Figure 3-3.

Figure 3-5. View of Storage Tank

3.1.3 Water Storage Facilities. The municipal water supply system currently consists of one new 950,000-l (250,000-gal) brick water storage tank located on a hill north of the community, as shown on Figure 3-5. The location of the tank is shown on Figure 3-3. The tank is presently not in use, awaiting further development of the community water system. Water supply wells and lines from the wells to the reservoir have not yet been constructed.

3.1.4 Piping System. The planned Limón de la Cerca water distribution system is presently incomplete. A 38-mm through 150-mm (1½-in through 6-in) diameter PVC distribution system and water mains connecting the distribution system to the new reservoir is presently being constructed.

3.2 Historical and Projected Water Demands

Water demand projections provide the basis for sizing and staging future water facilities. Water use and production records, combined with projections of residential population, provide the basis for estimating future water requirements. This section presents a summary of demographic information and water use data as well as the resulting projections of future water needs for Limón de la Cerca.

3.2.1 Demographics. Demographic information consisting of population, housing, and water system connections are described in this section.

3.2.1.1 Population and Housing. The community's population resides within ten colonias, with a planned maximum population of 13,500. The actual current population is not known, but is believed to be approaching 50 percent of the 13,500 figure based on field observations and information provided by FUNDEMEUN. The buildout population, by colonia, is presented in Table 3-3. The number of people per household is estimated to average six persons.

3.2.1.2 Commercial Establishments. There are several small commercial establishments in the community. A trade school to serve the colonias is presently under construction near the main highway.

3.2.1.3 Connections. There are several small connections to homes within the community at this time, except for some residental connections in Colonia Samaritana. However, once the planned water system improvements have been completed and the homes are connected to the distribution system, a total of 2,250 active connections are anticipated.

Table 3-3. Water Demands at Buildout

Colonia	Population	Average day water use			
		38 lpcd[a]	151 lpcd[b]	10 gpcd[a]	40 gpcd[b]
Panamericana	1,260	47,696	190,785	12,600	50,400
Samaritana	1,980	74,951	299,805	19,800	79,200
Nueva Jersulén	1,848	69,954	279,818	18,480	73,920
Santa Fe	2,220	84,036	336,145	22,200	88,800
Juan Pablo II	1,590	60,188	240,752	15,900	63,600
Inglaterra	1,542	58,371	233,484	15,420	61,680
Loma Linda	1,098	41,564	166,259	10,980	43,921
Linda Henry	1,524	57,690	230,759	15,240	60,960
Testigos de Jehová	138	5,224	20,895	1,380	5,520
Iglesia de Cristo	300	11,356	45,425	3,000	12,000
Total	13,500	511,030	2,044,122	135,000	540,000

[a] Collect and carry supply condition.
[b] Piped water service.

3.2.2 Historical Water Use. Water production is the volume of water measured at the source, which includes all water delivered to customers, as well as unaccounted-for water. This section describes daily water production, maximum day demand, and unaccounted-for water.

<u>3.2.2.1</u> <u>Daily Water Production.</u> Daily water production for the community's five active wells is not known because the wells are not metered. However, it is known that the wells run on a limited and varying basis, typically only a few hours a day because of limited electrical power. Current daily water production is estimated to be approximately 227,125 liters per day (lpd) (60,000 gallons per day (gpd)) based on all wells pumping four hours per day.

For this project, a water meter was installed on existing Well LC4. The average day water production for a 47-day period from June 14, 2001 to July 31, 2001 from Well LC4 was 39,000 gpd. The maximum day water production measured during this period was 77,000 gpd.

<u>3.2.2.2</u> <u>Maximum Day Demand.</u> Daily demand fluctuates throughout the year based primarily on seasonal climate changes. Water demands are higher in the dry season and less in the wet season. System water production facilities must be sized to meet the demand on the maximum day of the year, not just the average. The maximum day peaking factor, which is defined as the one day of the highest water use during a one-year period, divided by the annual average water use, is estimated to be 1.5 for the purposes of this study.

<u>3.2.2.3</u> <u>Unaccounted-for Water.</u> Unaccounted-for water is miscellaneous metered water use such as distribution system and hydrant flushing, sewer cleaning, construction, system leaks, and unauthorized connections. Currently, the metering system is not in place and therefore an estimate of unaccounted-for water cannot be made at this time. Once the community homes are connected to a central distribution system, unaccounted-for water use may be substantial.

3.2.3 Unit Water Use. Unit water use factors, expressed as liters per capita per day, are developed to estimate future water needs based on the population projections discussed previously. The projected residential population is coupled with a unit water use factor per person to estimate future water needs.

The Design Report states that per capita water use in Limón de la Cerca is expected to be 150 lpcd (40 gpcd), assuming piped water is available to each residence (CH2MHill, 2001). A 150 lpcd consumption figure is consistent with data published by the World Bank (CH2MHill, 2001). For this study, it is assumed that the unit water use factor will be 150 lpcd once the water distribution system is connected to each residence. The current unit water demand, which considers water usage based on the current "collect and carry" system, is estimated at 38 lpcd (10 gpcd).

3.2.4 Projected Water Demands. Water demands for piped and "collect and carry" conditions at build-out are shown in Table 3-4. Average annual water demands under a piped water supply condition are expected to increase to 2,044,122 lpd (540,000 gpd) upon completion of the distribution system. The maximum day demand is projected to increase to 3,066,000 lpd

(810,000 gpd). Impacts to water use due to any conservation measures implemented in the future are not reflected in the projected water demands.

As indicated, the current well supplies are suitable for build-out assuming the continuation of the "collect and carry" system. However, the completion of the distribution system will result in an increase in per capta water consumption and will require significantly more source capacity. Based on this scenario, an additional 27 lps (423 gpm) will be necessary to meet maximum day demand upon completion of the distribution system to the community and after the community has been built out to 2,250 homes. The following chapter discusses the groundwater resources available to meet this demand.

Table 3-4. Projected Pumping Demands at Buildout

	Average day water use		Maximum day water use[a]		Source capacity					
					Required[c]		Available		Deficit	
	lpd	gpd	lpd	gpd	lps	gpm	lps	gpm	lps	gpm
Piped Water Supply Condition[b]	2,044,122 (1,420 lpm)	540,000 (375 gpm)	3,066,184 (2,131 lpm)	810,000 (563 gpm)	43	676	16	253	27	423

[a]Maximum day projected water demand based on assumed 1.5 maximum day peaking factor.
[b]Based on water use of 40 gpcd.
[c]Based on 20 hour/day pumping and meeting maximum day demand.

4.0 GROUNDWATER RESOURCES EVALUATION

The groundwater resource evaluation for Limón de la Cerca consisted of the review and analysis of existing geologic, hydrogeologic and groundwater resource information for the area. Following the initial records review, a site reconnaissance of the area was conducted, followed by the development of a conceptual model, and the performance of a field investigation which included drilling and testing of three wells to explore deep hydrogeologic conditions in the valley. Following data collection and interpretation, a numeric groundwater flow model was developed using data obtained during this evaluation. This chapter presents the results of the groundwater evaluation at Limón de la Cerca. Training in groundwater monitoring techniques was conducted for local staff, as described in Appendix F.

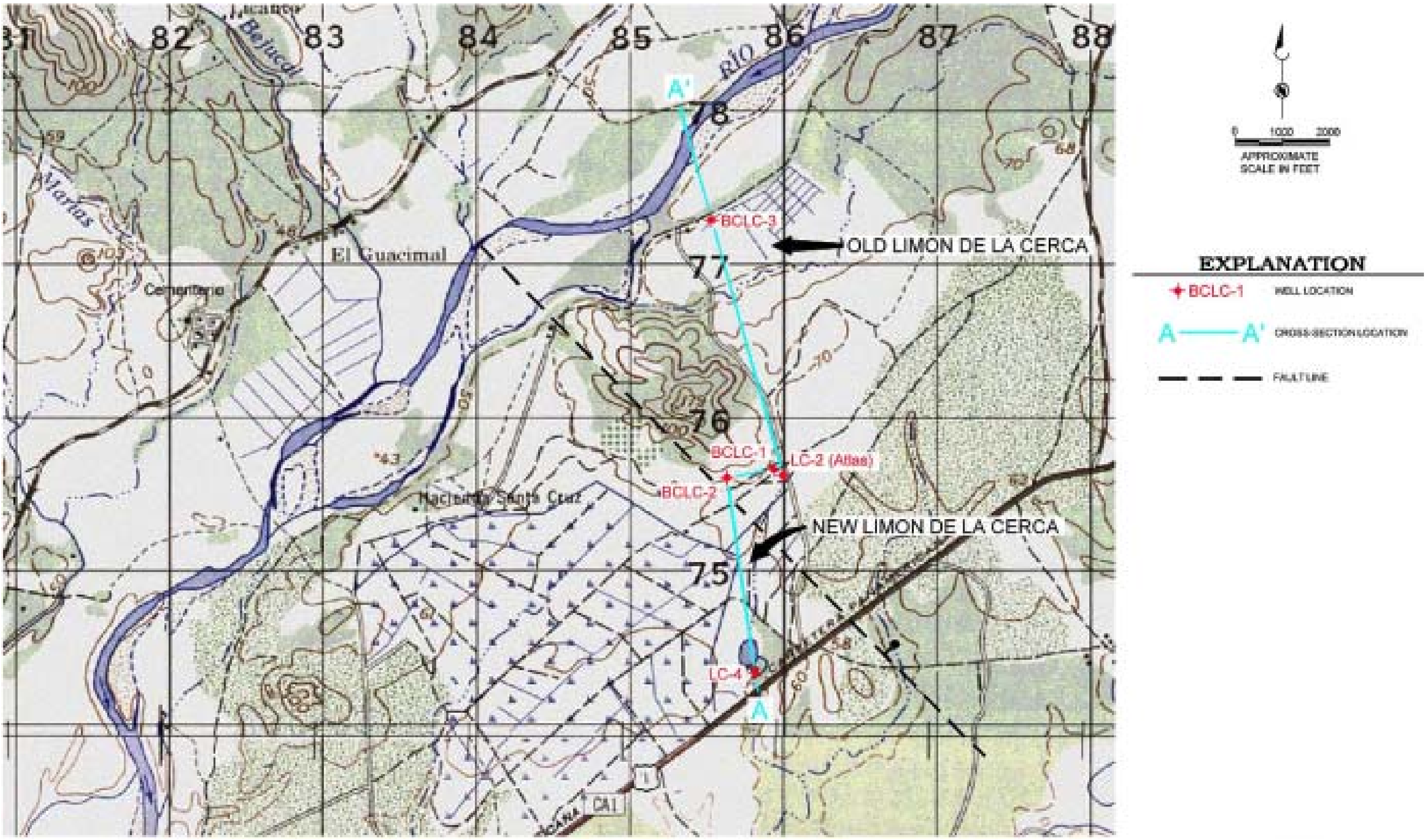
4.1 Conceptual Hydrogeologic Model

The initial conceptual model of the area was developed based on the understanding that the fractured igneous rocks of the upland areas serve as the major source of groundwater recharge to the alluvium and bedrock in the Limón de la Cerca area. The alluvial deposits are naturally divided into upper, middle, and lower terraces. Precipitation recharge to the northern and southern highlands flows through bedrock and sediments toward the valley and ultimately discharges to the Choluteca River. Based on information from local drilling companies, favorable groundwater production was believed to exist in the middle and lower terraces of alluvium and from the deeper bedrock fracture system. Available information indicated that production from the upper terrace deposits is limited and of insufficient quantities to provide for the needs of the community.

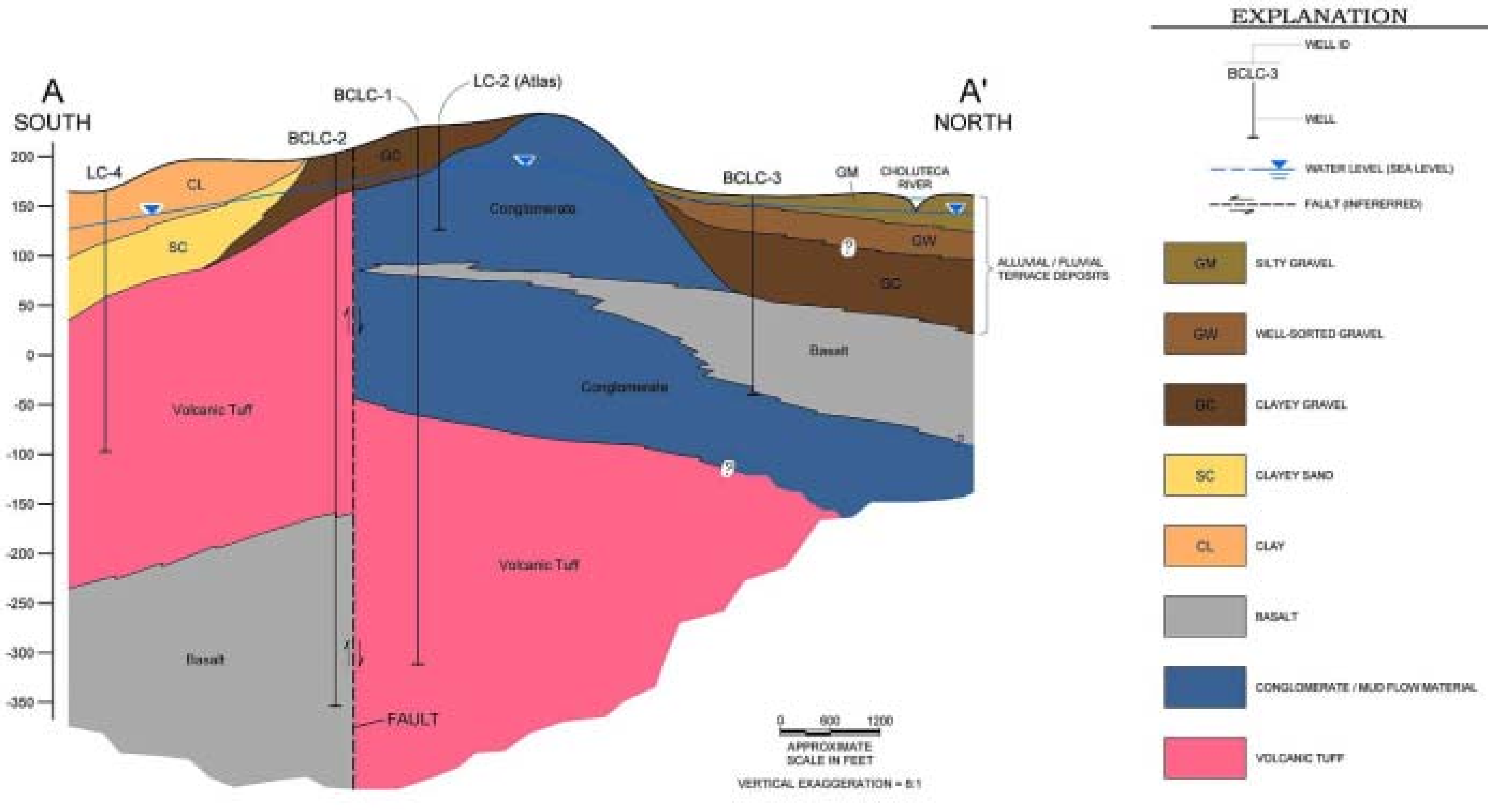
Based on the information gained from the field investigation, the early conceptual model was revised to show a complex hydrogeologic setting beneath the valley. The valley is surrounded by rugged uplands of igneous rocks, while the valley consists of a thin veneer of alluvium underlain by consolidated mud-flow (conglomerate/lahar-type) deposits, and various assemblages of igneous rocks.

A geologic cross-section profile was constructed from south to north from the Choluteca River, through the Limón de la Cerca study area. This cross-section is based on the lithology described at existing production well LC-4, new boreholes BCLC-1, BCLC-2, existing production well LC-2, and BCLC-3 (Figure 4-1). Existing production well LC-4 is located along the southern boundary of Limón de la Cerca, just north of the PanAmerican Highway. According to Servicios de Perforacion, S. de R. L. de C. Y. (SERPE) drilling records, lithology at well LC-4 consists of clay from the surface to 12.2 m bgs (40 ft bgs), then sand and minor amounts of clay from 12.2 to 24.4 m bgs (40 to 80 ft bgs). This material is interpreted to be alluvial and fluvial valley-fill deposits. Below, volcanic rock was encountered from 24.4 to 61 m bgs (80 to 200 ft bgs) (SERPE drill report, date unknown). The lithology of LC-2 is reported as alluvium from 0 m to 12.2 m bgs (0 ft to 40 ft bgs) and volcanic rock from 12.2 to 38.1 m bgs (40 to 125 ft bgs).

The lithology described in the profile is consistent with the complex geologic history of periods of uplift, volcanism, faulting and erosion in the area (Figure 4-2). The thick section of conglomerate



BROWN AND CALDWELL	DATE 2-13-02	SITE Limón de la Cerca, Republic of Honduras	FIGURE 4-1
	PROJECT 21143	TITLE Cross Section Location Map	



BROWN AND CALDWELL	DATE 2-13-02	SITE Limón de la Cerca, Republic of Honduras	FIGURE 4-2
	PROJECT 21143	TITLE Cross Section A-A' illustrating Geology	

observed at test well BCLC-1 is interpreted to be ancient valley-filling mudflow/lahar-type deposits from events emanating from the surrounding highlands. Following faulting and uplift, this section of conglomerate, which is more erosion resistant, remained as a topographic high in comparison to surrounding less resistant terrain. Between BCLC-1 and BCLC-2, a fault is inferred with BCLC-2 on the upthrown side. The volcanic tuff and basalt observed at test well BCLC-2 are likely representative of the thick layer of pyroclastic and igneous rocks reported in this area. Fault movement resulted in the juxtaposition of volcanic tuff against the thick section of conglomerate at BCLC-1. Both units are fractured, however, it is uncertain whether groundwater can flow across the fault line. To the north, the geology between BCLC-1 and BCLC-3 is interpreted to be alluvial terrace deposits of the Choluteca River, which has cut a broad floodplain into the volcanic materials seen in the surrounding uplands.

4.2 Field Investigation Program

The field investigation conducted at Limón de la Cerca was designed to evaluate deeper groundwater resources for the growing community as well as further define available groundwater resources in the Rio Choluteca alluvium. The primary purpose of evaluating deeper groundwater supplies was to understand if deeper aquifers could be developed near the reservoir and to reduce the potential for subsurface contamination associated with surface discharge of wastewater. Previous investigations and several existing wells revealed that the fracture network in bedrock, below the alluvium, could contribute significant groundwater supplies. It was assumed that groundwater recharge to the valley was occurring from the surrounding highlands of igneous rocks. Therefore, the first objective of the field investigation was to conduct a preliminary study of the nature and extent of the fracture system, as well as investigate whether the fractured bedrock would provide sustainable groundwater supplies for the area. The second objective was to explore groundwater production zones within the valley alluvium.

Figure 4-3. Drilling of Test Well

In support of these objectives, the field investigation consisted of a surface geophysical survey, drilling and installation of two test wells in bedrock and a monitor well in the alluvium (Figure 4-3), geophysical logging of the boreholes, down-hole video surveys of the two bedrock test wells, and water quality sampling of wells in the vicinity of Limón de La Cerca. For both the bedrock and alluvial wells, aquifer testing was conducted in order to assess well specific capacity and aquifer transmissivity. This section summarizes the findings of these field investigations. Appendix C presents the field investigation results.

4.2.1 Surface Geophysical Survey. To better understand the regional geology and locate potential laterally extensive groundwater horizons, a surface geophysical survey was conducted in the area surrounding Limón de la Cerca. The geophysical survey consisted of collecting both seismic refraction and seismic reflection data. The primary objective of this survey was to define the depth to bedrock in areas where knowledge of the depth to bedrock was limited, and to analyze subsurface stratigraphy for potentially buried bedrock valleys containing thick sand and gravel deposits.

Seismic refraction surveys utilize seismic energy that return to the ground surface after travelling along refracted ray paths, and is used for locating interfaces of different acoustic impedances. After an energy pulse is purposely released to the surface (Figure 4-4) the resulting ground motion is detected at the geophones (Figure 4-5) and digitally recorded by the seismograph. A sledge hammer was used as an energy source for this study. Three high-resolution seismic refraction lines, each approximately 1,000 m (3,281 ft) long, were located along the east, south, and west sides of Limón de la Cerca.

Figure 4-4. Sledgehammer is the Energy Source for the Surface Geophysics Surveys

Additionally, a single seismic reflection line was conducted along the eastern border of Limón de la Cerca. Information from this line was collected to further map the bedrock from north to south to determine the presence of potential deeper groundwater producing structures.

Figure 4-5. Geophone - Used for Surface Geophysics

Three major geologic horizons were detectable using seismic refraction. The first layer is interpreted to be a very fine-grained, unconsolidated clay layer. The second layer is similar to the first but is more consolidated. The third layer is interpreted to be bedrock, moderately consolidated. The seismic refraction survey was capable of clearly differentiating the contrast between these horizons and was used to map the alluvial stratigraphy, and the nature of the contact bedrock surface. Because the refractive velocity of the bedrock remained relatively constant across the three survey lines, it is believed the upper bedrock lithology and physical characteristics are quite similar within the study area. The seismic reflection data supported the results of the refraction survey, but also indicate that below the upper fractured bedrock, the rock was much harder, possibly with less fracturing.

The surface geophysics survey in Limón de la Cerca was completed by Terra-Dynamics in July and August 2001. Results are included in Appendix B of this report.

4.2.2 Test Well and Monitor Well Installation. The well drilling for this project was concentrated to an area within 1.5 km (0.9 mi) around the storage tank considering the future pumping cost. Drilling budget constraints did not allow the evaluation to extend towards the Sampile River, which is approximately 4 km (2.5 mi) east of Limón de la Cerca.

Figure 4-6. Open Borehole BCLC-2

Two open borehole test wells (BCLC-1, BCLC-2) and one screened monitor well (BCLC-3) were installed as part of the Brown and Caldwell field investigation (Figure 4-1). Test wells BCLC-1 and BCLC-2 are located along the northern border of the new community, approximately 500 m and 200 m (1,640 ft and 656 ft), respectively, from the new water storage tank. Test well BCLC-1 is located adjacent to existing production well LC-2. Both wells are located on the southern flank of El Carmen Mount. Test wells BCLC-1 and BCLC-2 were drilled to depths of 144.8 m and 152.4 m bgs (475 ft and 500 ft bgs), respectively, (reportedly the deepest borehole penetrations in the area) to explore production in the lower fractured bedrock. The drilling of test hole BCLC-2 is pictured in Figure 4-6.

The third well, BCLC-3 is located approximately 1.5 km (93 mi) northeast of Limón de la Cerca and northeast of El Carmen Mount. The well was installed to explore the production potential of the Rio Choluteca alluvium. Details of the well drilling and construction are provided in Appendix C. A summary of well construction and completion details is provided in Table 4-1 below.

Table 4-1. Summary of New Well Completion Details

Well	Borehole depth		Total depth of well		Depth of surface casing		Function
	M, bgs	ft, bgs	m, bgs	ft, bgs	m, bgs	ft, bgs	
BCLC-1	144.8	475	135	443	16.8 outer csg 64 inner csg	55 outer csg 210 inner csg	Test well to evaluate deep fractured bedrock
BCLC-2	152.4	500	146	479	18.3 outer csg 94.5 inner csg	60 outer csg 310 inner csg	Test well to evaluate deep fractured bedrock
BCLC-3	47.2	155	45.7	150	None	None	Monitor well to evaluate lower and middle alluvial terrace deposits

bgs = below ground surface
csg = casing surface grade

After completion of the exploratory borehole for test well BCLC-1, geophysical logging was conducted. In addition, downhole video was recorded on test wells BCLC-1 and BCLC-2. The geophysical logging suite included spontaneous potential, point resistivity, gamma, temperature, and caliper. The geophysical logs are also presented in Appendix C.

Drill cuttings and down-hole video indicate test well BCLC-1 consists of sandy-clay with gravel from the surface to a depth of 12.2 m bgs (40 ft bgs); interpreted to be primarily alluvial in origin. From 12.2 m to 73.2 m bgs (40 ft to 240 ft bgs), a highly consolidated thick conglomerate was observed. The conglomerate consists of poorly sorted, moderately cemented, sub-rounded to angular clasts, ranging in size from pebbles to cobbles. Within this conglomerate, a thin horizon of basalt was observed at a depth of 32 m to 33.5 m bgs (105 ft to 110 ft bgs). Video images indicate the conglomerate is lightly to moderately fractured, with calcite filling much of the fracture voids. Below the conglomerate, from 73.2 m to 144.8 m bgs (240 ft to 475 ft bgs), moderately to highly fractured welded volcanic tuff was observed. The lithologic and geophysical profiles for this test well are provided in Appendix C.

Similar to test well BCLC-1, the test hole for BCLC-2 was drilled to a total depth of 152.4 m bgs (500 ft bgs) to evaluate the production potential of the deeper fractured bedrock. Drill cuttings indicated the presence of gravelly-sand and silt to a depth of 15.2 m bgs (50 ft bgs), also interpreted to be alluvial material. Below this alluvium, from 15.2 m to 102.1 m bgs (50 ft to 335 ft bgs), welded volcanic tuff was observed. Video images indicated this tuff to be lightly to moderately fractured, with most of the void spaces occluded by calcite. Below the tuff, from 102.1 m to 152.4 m bgs (335 ft to 500 ft bgs), moderately fractured basalt was observed. The lithologic and well construction profiles for this test well are provided in Appendix C.

The test hole for monitor well BCLC-3 was drilled to a depth of 47.2 m bgs (155 ft bgs) to explore the production potential of the Choluteca River valley alluvium. Inspection of drill cuttings indicated from the surface to 24.4 m bgs (80 ft bgs), alternating layers of unconsolidated silty-, sandy- and clayey-gravels were observed. These layers are interpreted to be representative of the river terrace deposits. Below the alluvium, highly weathered and fractured basalt was penetrated down to the bottom of the test hole (47.2 m (155 ft)). A permanent monitoring well was installed at this location to a depth of 45.7 m bgs (150 ft bgs). The well completion diagram and lithologic and geophysical profiles for this monitor well are provided in Appendix C.

4.2.3 Aquifer Testing. Short-term and long-term aquifer tests were performed on selected wells to evaluate the water resource development potential of both the fractured bedrock units and alluvium. A step rate discharge test was first performed on test well BCLC-1. Because it was the highest yielding well of the two newly installed bedrock wells, BCLC-1 was selected for the long-term, 72-hour, aquifer pumping test. During the test, the well maintained a flow rate of 5.7 lps (90 gpm) with a maximum draw-down of about 29 m (95 ft). The results of the pump test are outlined and illustrated in Appendix C.

Due to marginal yields, very limited tests were conducted in wells BCLC-2 and BCLC-3. Results for the step rate discharge test performed on well BCLC-2 indicated that sustainable yields from this well would likely be less than 132.5 lpm (35 gpm). Similarly, the aquifer step rate discharge test conducted on alluvial well BCLC-3 indicated that well yields would likely be less than 1.3 lps (20 gpm). Data results for pump tests conducted at BCLC-2 and BCLC-3 are outlined and illustrated in Appendix C.

Available records indicate that an aquifer test was performed on existing well LC-4 by SERPE after its construction. During the 24-hour constant rate discharge test, the well maintained a flow rate of 442.9 lpm (117 gpm) with a maximum draw-down of 7.87 m (26 ft). Currently, existing well LC-4 is used for domestic water purposes and pumps intermittently at approximately 757.1 lpm (200 gpm) (0.76 m^3/minute) (Hidro Sistemas, 2001). It is assumed for this study in Chapter 3 (Table 3-2) that well LC-4 has a capacity of 443 lpm (117 gpm).

4.2.4 Water Quality Survey. Groundwater samples were collected from each of the wells installed by Brown and Caldwell during this investigation. In addition, the following existing wells at Limón de la Cerca were included for water quality evaluation: LC-1 (Ricardo Soriano), LC-2 (Atlas), LC-3 (Bolsa Samaritan), and LC-4 (Panamericana). These municipal wells were included in the groundwater quality monitoring in order to provide a comprehensive understanding of the general water quality in Limón de la Cerca. The results of the water quality testing are summarized in Table 4-2 and presented in Appendix C. Only some of the constituents with drinking water standards were included in the survey.

Table 4-2. Summary of Well Analytical Results

Analytical constituent	Drinking water standard[c]	Test wells			Existing wells[a] (range)
		BC LC-1	BC LC-2	BC LC-3	
General					
Acidity	mg/l[g]	30	8	33	3.6-30
Alkalinity	mg/l CaCO3[g]	140	127	158	144-158
Chloride	mg/l[g]	7	6.5	13.5	8-10.5
Conductivity	us/cm[g]	483	228	73.6	261-290
Hardness	mg/l CaCO3[g]	84	44	140	100-124
Iron	0.3[f] mg/l	0.02	0.01	0.07	<0.03-0.03
Manganese	0.5 mg/l (P)[e]	<0.03	<0.03	0.15	<0.03
Nitrate	50 mg/l	7.12	1.03	0.391	3.17-7.1
Potassium	10 mg/l	2.7	2.47	4.9	2.52-3.57
Metals					
Antimony	0.005 mg/l (P)[e]	<0.005	<0.005	<0.005	<0.005
Arsenic	0.01 mg/l (P)[e]	<0.005	0.0079	<0.005	<0.005
Zinc	3 mg/l	0.175	<0.02	0.0537	<0.02-0.0537
Bacteriology					
Total Coliform	UFC/100 ml	16	34	--[d]	--[d]
Fecal Coliform	UFC/100 ml	0	--0	--[d]	--[d]
Pesticides	(range)[b] mg/l	--[d]	--[d]	None detected	--[d]
Herbicides	(range)[b] mg/l	--[d]	--[d]	None detected	--[d]
Volatile Organics	(range)[b] ug/l	--[d]	--[d]	None detected	--[d]

Source: SPL Houston Laboratory and Jordanlab Laboratorio de Analysis Industrial laboratory results. Test dates vary.
Note: Numbers in bold are those over the drinking water standard.
UFC – must not be detectable in any 100 ml sample.
[a] Existing wells that exceed drinking water standard.
[b] Drinking water standard varies by individual constituent.
[c] World Health Organization, 1996. Guidelines for Drinking Water Quality, 2nd ed. Vol 2 Health criteria and other supporting information and Addendum to Vol. 2, 1998.
[d] Lab reports not available/not tested for this constituent.
[e] (P) – provisional guidance value for constituents for which there is some evidence of a potential hazard but where the available information on health effects is limited; or where an uncertainty factor greater than 1000 has been used in the derivation of the tolerable daily intake.
[f] Levels likely to give rise to customer complaints.
[g] No drinking water standard.

The spacial distribution of wells provides a sufficient amount of data to establish a water quality baseline to build on in the future. Groundwater monitoring procedures are presented in Appendix E.

Results for each of these constituents were compared to the Guidelines for Drinking-Water Quality as published by the WHO. It should be noted that while the Honduran government has not established country-specific guidelines for drinking-water quality, the Honduran Ministry of Health has accepted the guidelines established by WHO.

A review of the data shows that all of the sampled wells provide water that meets drinking water standards. The exception is that most of the sampled wells had coliform present. This result indicates bacteriological contamination that can be easily addressed with disinfection.

4.3 Numerical Simulation of Well Fields

A numerical groundwater flow model was constructed for Limón de la Cerca as a potential interpretative tool to evaluate possible groundwater resources for the community. The process produced a groundwater flow model consistent with our understanding of hydrogeologic conditions in the area.

The original intent of the model was for use in the evaluation of potential groundwater resources. However, due to the complexity of the geology and hydrogeology, as well as the uncertainty of accurately defining the conceptual hydrogeologic model for the site, it is recommended the use of this preliminary groundwater model be limited to developing a general understanding of potential groundwater resources for the community. Information collected to date, the conceptual geologic and hydrogeologic model developed for Limón de la Cerca, and this groundwater flow model should serve as the basis for an initial understanding of the site and be used accordingly.

Complexities in the changes of flow through the valley, a "pumping case" scenario, was modeled using the initial "base case" model with the four existing production wells (LC-1, LC-2, LC-3 and LC-4). The wells were simulated pumped at varying rates. The potentiometric surface changed slightly by approximately 1 to 2 m (3.3 to 6.6 ft), however, no change was observed on the general groundwater flow direction through the valley. The complete results of the modeling are provided in Appendix D of this report.

As additional geologic and hydrogeologic data are collected, the site conceptual model and groundwater flow model can be refined, thereby increasing the groundwater flow model's effectiveness to be used as a tool to further define and manage the community's groundwater resources.

4.4 Aquifers and Recommended Well Field

Results of this investigation indicate that marginal water supplies are present within the upper 150 m (500 ft) of bedrock in the vicinity of the newly constructed water supply tank. However, due to the complexity of the geology and hydrogeology, the sustainability of the resource is uncertain.

Available data indicate that fracture flow in the igneous bedrock plays an important role in groundwater recharge. However, the presence of faults and discontinuous lithologic units may hinder recharge flow pathways. This uncertainty was demonstrated by comparing the results from BCLC-1 and BCLC-2. Preliminary results from BCLC-1 indicate that sustainable rates would be in the range of 227 to 303 lpm (60 to 80 gpm). BCLC-2, which is located approximately 274.3 m (900 ft) from BCLC-1, is projected to yield less than 57 lpm (15 gpm). Furthermore, during the aquifer test at BCLC-1, no groundwater response was observed in BCLC-2. These results demonstrate the uncertainty and complexity of the hydrogeologic system, which limits the ability to accurately predict production yields.

Preliminary results of this investigation also indicate that the alluvial deposits located on the margins of the Rio Choluteca flood plain do not yield sufficient supplies for municipal purposes. Existing well LC-4, located in the southern portion of the community, has an estimated sustainable yield of approximately 1,136 lpm (300 gpm). This well is screened within the lower portion the alluvium and the upper portion of the bedrock. Our results indicate that the bulk of the water is being produced from fractures within the upper portion of the bedrock. BCLC-1 and BCLC-2, where the majority of the water was produced from the lower portion of the bedrock, demonstrates the heterogeneity of the aquifer system. This localized fracture system in the vicinity of LC-4 has the potential for sufficient supplies for municipal purposes.

4.5 Potential Contamination Sources

There are several potential sources of contamination to the shallow fresh water aquifer in the vicinity of Limón de la Cerca. Much of the local economy is driven by agriculture and animal husbandry. As a result, there are defined sources of nitrate and coliform. Stormwater runoff carrying concentrations of nitrate and coliform could migrate from the surface and percolate to the groundwater zones in the alluvium and fractured bedrock. Similarly, many of the existing and new residential areas possess inadequate sanitary facilities and most rely on latrines that discharge directly to the ground. In addition, many of the existing wells in the area are screened to the surface, which provide direct vertical conduits for contaminants to migrate from the shallow subsurface to saturated zones below. The new sewer system that was recently built may concentrate wastewater collection close to LC-4, potentially posing a contamination threat.

4.6 Summary of Findings

Results of this investigation indicate that wells installed into the fractured bedrock system, near the new storage tank, most likely would not provide sufficient yields to meet this demand. Similarly, the shallow aquifer in the Choluteca alluvium, north of the community would not provide sufficient groundwater supplies. The localized fracture system in the vicinity of well LC-4 is likely to have the potential to provide sufficient supplies for municipal purposes.

Because of complex geology and hydrogeology in the area, it was not possible to develop a reliable numeric flow model for this study that provides information regarding the sustainability of the alluvial and bedrock aquifers. Information from the numeric model was to be used in this study in the evaluation of potential groundwater resources in the vicinity of Limón de la Cerca. Given the uncertainty of the hydrogeologic conditions and the inability to develop an accurate conceptual model, use of the numeric model was limited for this study to develop a general understanding of potential groundwater resources for the community. The site conceptual model and groundwater flow numeric model may be refined in the future by the community, and possibly used as evaluation tools as additional information becomes available. It is important that a groundwater monitoring program consisting of measuring groundwater levels, extraction volumes, and quality be continued. A monitoring program manual is included in Appendix F. The training conducted on groundwater monitoring for this project is described in Appendix G.

5.0 WATER RESOURCES MANAGEMENT SYSTEM

The Water Resources Management System (WRMS) is a desktop computer application developed to store, manage, and analyze technical information gathered and generated for this project. The application is a management tool that can be used by the municipalities and other decision-makers to support sustainable management of their groundwater resources. The system is composed of both a data management system and a geographic information system (GIS) linked together as one application. Through the WRMS, users can:

- manage and generate reports for wells, storage tanks, and springs;
- view well logs and well completion diagrams;
- analyze water quality and water level data;
- track statistics on water use; and
- view wells, water quality information, and aquifer characteristics on maps of the study area.

The WRMS is considered an important component for the water resource management plan. The system is briefly described in this chapter and is described in more detail in the Water Resources Management System Users Guide (Appendix E). The training that was conducted in the use of the WRMS is described in Appendix H. The application consists of two primary components; a data management system and a GIS. The application is written so that the two components work together and function as one system. Data are shared back and fourth between the data management system and the GIS.

The data management system used is Microsoft Access, which is a relational database designed to efficiently manage complex data. The data are stored in a series of tables. Each table stores a different type of information, and each table is linked to others by a key field that defines the relationship. For example, one table contains a record of each well, while another table contains all the water level measurements. The table containing the water levels also contains the name of each well so that it can be linked back to the appropriate well in the well table. This way, detailed information on each well and water level measurements can be stored most efficiently, without the need to maintain the same piece of information more than once, which would potentially introduce erroneous data into the system.

The GIS used is ArcView®, by Environmental Science Research Institute. A GIS is an electronic mapping and analysis system. The power of GIS lies in its ability to manipulate, display, and analyze information on a map by linking map elements to attribute data in a database. For example, a well whose location is identified as a dot on the map is connected to the construction data, sampling results, and water level information in the database. The user can post any of this information as text on the map, choose specific symbols or colors to represent these data, and overlay this layer of information on other map features. Because the data management system and GIS work together, it provides the user with a powerful set of management and analysis tools.

Both of these components are linked through a common interface developed in Microsoft Visual Basic. The interface is a series of screens that guide the user through various application functions.

Through the interface, the user can enter or update data, view reports, generate graphs, display scanned images, and create customized maps. The interface can be displayed in English or Spanish, uses water resource terminology, and is designed to be user-friendly. Through this interface, municipalities will be able to continue to update their water resource data and use it for decision-making in the future.

5.1 Benefits of the WRMS

The WRMS consolidates, perhaps for the first time, the most critical water resource information for a municipality. It provides a central place to manage, analyze, and display water resource information in both map and tabular form. The WRMS accommodates all major types of information needed for sound water resource management including data on wells and other water sources, future demand and growth, infrastructure and organizational boundaries, and water quality and aquifer characteristics.

Because the system is designed to accommodate additional data as more information is collected and wells are created or modified in the future, it can be used to facilitate sound water resource decision-making in the future. It is easy to use and requires minimal training, which will facilitate continued system use. It uses a standard methodology for identifying and prioritizing future well sites, which will allow municipalities to continue to apply a consistent planning approach.

5.2 Use and Management

The WRMS is designed to work in conjunction with the findings of this report. Most of the data collected or developed for the report are contained in system, and are available for continued analysis, display, and incorporation with new data as it is collected. The system can be used to view and explore additional details of the existing water system.

The WRMS should be used to provide a common environment for communication among stakeholder agencies for water resource planning. The system provides a consistent view and methodology for analyzing water resource data. Consistently using it as a communication tool among stake-holders will make the sometimes confusing and complex technical information easier to understand. New data, such as new wells, additional sampling results, or new water level measurements should be entered into the system on a regular basis (annually) in order to have the most up-to-date information available for decision-making.

5.3 Limón de la Cerca Data

Table 5-1 summarizes mapping information collected on Limón de la Cerca. This data is included for review in the WRMS. There are 21 wells with information collected. Eight wells; BCLC-1, BCLC-2, BCLC-3, LC-1, LC-2, LC-3, LC-4, and Luis; have water quality information in the WRMS.

A compact disk containing the WRMS and all of the Limón de la Cerca data described above is included with this report.

Table 5-1. Limón de la Cerca GIS Data Dictionary

File name	File type	Description	Date	Source	Scale of source data
Topo-choluteca-urbanareas.shp	shape	Polygon of Choluteca urban development based on topographic map		Scanned topographic map	
Cad&BC-choluteca-pipelines.shp	shape	Pipeline 11/2 though 6 inch existing in Limón de la Cerca – currently not connected to groundwater wells.		CAD and BC	
Cad-choluteca-growthareas.shp	shape	Urban growth areas from CAD files		CAD	
Cad-choluteca-rivers.shp	shape	Rivers in the Limón de la Cerca and Choluteca area. Also traced from topographic map		CAD	
Cad-LDLC-roads.shp	shape	Roads and hwys through Limón de la Cerca		CAD	
Colonies-poly.shp	shape	Polygons of each of the ten colonias in Limón de la Cerca.			
LDLC-urbanarea.shp	shape	Polygon of Limón de la Cerca urban area			
Choluteca-utm.tif	image	Scanned topographic map in Nad 27 coordinates			
Choluteca cad.shp	shape	CAD file aligned to NAD 27 – entire CAD file with multiple layers		CAD	
CAD-Choluteca-urbanarea.shp	shape	Choluteca urban area based on information from CAD files.		CAD	
CAD-Choluteca-munibndry-poly.shp	shape	Polygon of municipal boundaries based on CAD municipal boundary line for Choluteca. Most of the polygon is estimated based on the municipal line from CAD-choluteca-muniboundary.shp file.		CAD/BC	
CAD-Choluteca-munibndry.shp	shape	Municipal boundary line marking the partial municipal boundary of Choluteca (between the City of Choluteca and Limón de la Cerca).		CAD	
CAD-Choluteca-roads.shp	shape	Major and minor roads in and around Choluteca. Does not include minor roads around Limón de la Cerca.		CAD	
CAD-utm.shp	shape	Entire CAD file information on Limón de la Cerca including streets, pipes, etc.		CAD	
CAD-Choluteca-growth areas.shp	shape	Choluteca growth areas		CAD	
Chltc1-grd-av	ArcView® grid	Based on vector contour files. Arc info used to convert to grid. ArcView® used to convert grid to ArcView® grid.	2001	Intec Americans	30 meter, 1 arc second
Chltc2-grd-av	ArcView® grid	Based on vector contour files. Arc info used to convert to grid. ArcView® used to convert grid to ArcView® grid.	2001	Intec Americans	30 meter, 1 arc second
Choluteca-vect-1of2.shp	shape	Vector contour files purchased from Intec Americas.	2001	Intec Americans	30 meter, 1 arc second
Choluteca-vect-2of2.shp	shape	Vector contour files purchased from Intec Americas.	2001	Intec Americans	30 meter, 1 arc second

6.0 RECOMMENDED GROUNDWATER RESOURCES MANAGEMENT PLAN

This section presents recommendations to ensure water supply sustainability for the Limon de la Cerca resettlement community. Recommendations include drilling of additional water supply wells, implementing a groundwater monitoring program, wellhead protection, utilizing the water resources management system, more effective water utility management, and additional studies.

6.1 Drilling Plan

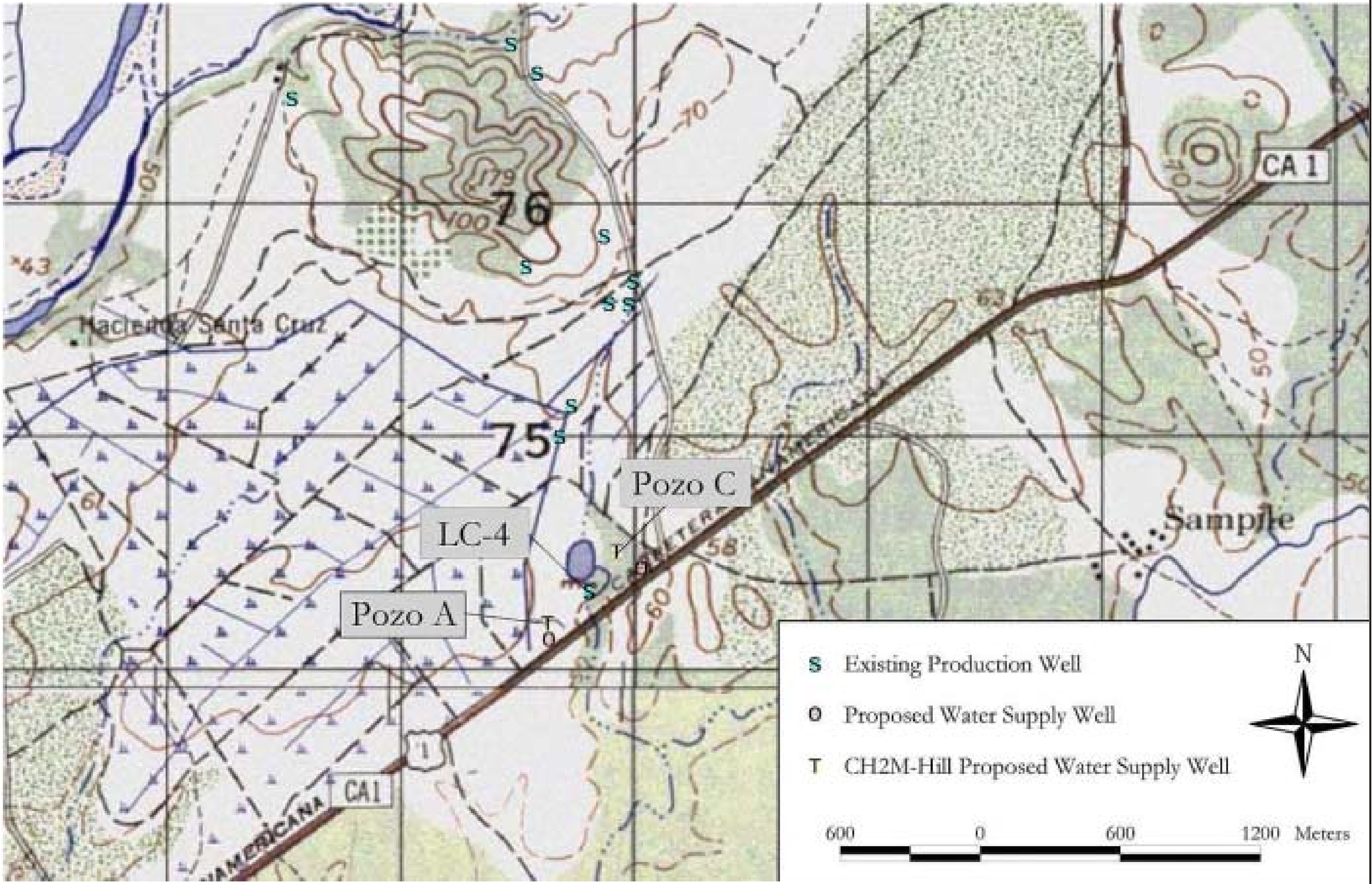
To meet maximum day demand at buildout, a total water supply of 43 lps (675 gpm) is expected to be required. The rate of 43 lps (675 gpm) is based on supply wells pumping for a maximum duration of 20 hours per day. Restricting the pumping of wells to no more than 20 hours per day results in increased reliability and longevity of pumps, allows for periodic maintenance of pumps and wells, and provides a water supply safety factor. Based on our analysis, the existing wells can currently supply approximately 16 lps (250 gpm). To meet projected future water supply needs, Brown and Caldwell recommends the following:

1. Redrill existing well LC-4 to increase its' capacity and protect water quality, and

2. Drill one or two additional water supply wells.

The current capacity of LC-4 is approximately 8 lps (125 gpm). Brown and Caldwell estimates that if LC-4 is re-drilled, and a larger diameter casing is installed, the capacity of LC-4 may be increased to 19 lps (300 gpm). Brown and Caldwell recommends redrilling Well LC-4 to approximately 300 ft bgs and reaming it to a diameter that can accommodate a 10-inch-diameter casing. To reduce the risk of contamination from surface domestic wastewater sources, the well should be screened at a depth starting at 70 ft bgs, rather than 40 ft bgs, the existing screened depth. In addition, after completing the new well, Brown and Caldwell recommends that aquifer pump tests be conducted to more accurately assess the maximum sustainable yield from this well.

In addition to the redrilling of LC-4, Brown and Caldwell recommends the installation of one or two additional wells, depending on the yield achieved with the first new well. Brown and Caldwell recommends drilling the first well approximately 225 to 300 m (750 to 1,000 ft) to the southwest of existing well LC-4, along, and just north of the PanAmerican Highway, near the proposed location of CH2MHill Pozo A (Figure 6-1). Brown and Caldwell recommends that this well be drilled to approximately 300 ft bgs, be constructed with 10-in-diameter casing, and have a screened interval from70 ft bgs to the total depth of the well. Brown and Caldwell recommends that a 72-hour aquifer test be performed once the new well(s) are installed. However, please be aware that field conditions and aquifer test results may warrant different construction specifications than those recommended above. In addition, although Brown and Caldwell believes it is likely that this well will produce between 9 lps (150 gpm) and 19 lps (300 gpm), it is possible that the highly variable geologic and hydrogeologic conditions may result in a lower sustainable yield, making this well impractical for use as a water supply well.



BROWN AND CALDWELL

DATE	SITE	FIGURE
2-13-02	Limón de la Cerca, Republic of Honduras	6-1
PROJECT	TITLE	
21143	Proposed Water Supply Wells	

If the redrilled LC-4 and the first proposed additional well do not meet supply requirements, Brown and Caldwell recommends that a second water supply well be drilled approximately 225 to 300 m (750 to 1,000 ft) northeast of existing well LC-4, also along, and north of the PanAmerican Highway. This proposed well location is approximately 1500 m (500 ft) south and east of CH2MHill proposed well Pozo C (Figure 6-1). Preliminary construction recommendations for this well are the same as the first additional well recommended by Brown and Caldwell, as described above.

6.2 Groundwater Monitoring

An important component of managing the current water supply in Limón de la Cerca and ensuring compliance with drinking water standards is the development and maintenance of a regular groundwater monitoring program. A regular monitoring program will ensure compliance with drinking water standards and will provide a useful tool for tracking groundwater quality and useage, as well as help with growth planning in the future. Quarterly monitoring of a groundwater monitoring well network is suggested for Limón de la Cerca. Brown and Caldwell recommends that the following wells be included in the monitoring well network: LC-1, LC-2, LC-3, LC-4, Iglesia Cristo Rey, BCLC-1, BCLC-2, BCVLC-3, Luis, Pozo Julian Herrera, Sra. Edith, Sr. Pacheco, Colonia Gracias a Cristo, Colonia Marcelino Champagnat. Brown and Caldwell has surveyed and monitored groundwater elevations from each of these wells. This information is included in the water resources database established for Limon de la Cerca.

There are several components that contribute to a successful monitoring program, each of which are equally important. These components include groundwater level data collection, groundwater production data collection, water sample collection, analysis of water samples and review, and compilation and understanding of water chemistry results. Each of these components is necessary in order to maintain a successful groundwater monitoring program. Information regarding the steps necessary to complete a monitoring program are outlined in the Groundwater Level and Monitoring Program, Field Manual, December 2001, included as Appendix F. This document was distributed to various members of the municipality during the groundwater level and monitoring training provided by Brown and Caldwell in December 2001.

Data collected during groundwater monitoring should be input into the project database established for Limon de la Cerca.

6.3 Wellhead Protection

The most effective means in protecting the groundwater quality used for public water supply in Limón de la Cerca is establishing a wellhead protection program. Wellhead protection is the practice of managing the land area around a well to prevent groundwater contamination. Prevention of groundwater contamination is essential to maintain a safe drinking water supply.

Groundwater may become contaminated through natural sources or numerous types of human activities. One of the main causes of groundwater contamination induced by human activity is the effluent from septic tanks, cesspools, and latrines. Although each disposal system releases a relatively small amount of waste into the ground, the large number and widespread use of these systems results in a significant contamination source. Similarly, improper disposal of gray water, hazardous wastes, leaking fuel storage tanks, and chemical storage and spill sites are sources of contamination to groundwater.

Development of a wellhead protection plan for Limón de la Cerca consists of five key steps that are described in Appendix G. The control measures included as part of a wellhead protection plan should be incorporated into municipal regulations to ensure control on water use and to protect the area covered with dense vegetation that represents potential groundwater recharge areas through rainfall infiltration.

6.4 Water Resource Management System

Brown and Caldwell developed a Water Resources Management System to store, manage, and analyze water resource related data gathered and generated for this project. This desktop computer application is a management tool that can be used by the municipalities and other decision-makers to sustainably manage their groundwater resources. The system is composed of both a data management system and a geographic information system linked together as one application. A copy of this system is included in this report. It is recommended that this database be regularly updated by the municipality. The database includes information gathered during the monitoring of the wells described in Section 6.2.

6.5 Water Utility Management

An important aspect of ensuring a sustainable water supply is having a functioning water utility with the proper organizational structure. The water utility is responsible for properly managing, operating, and maintaining the water system, and must be financially self-sufficient. Several water utility management recommendations are listed below.

1. Verify that a complete list of all water system customers is available. If not, prepare a list of all customers that includes descriptive information for each customer. This information would include name, address, service line size, and type of customer (residential, commercial, etc.);
2. develop a financial plan for the water utility that establishes budget needs and defines an equitable rate structure. Ensure that users are charged for and pay for water supply;
3. the water utility should have a governance structure, such as a board of directors, that meets regularly (minimum of every three months) and provides policy direction;
4. the water utility should have adequate staff that is trained on a regular basis to address operational and maintenance needs. The appropriate staffing needs for Limón de le Cerca should be defined; and
5. investigate possible sources of grant and loan financing to help improve the water system.

6.6 Summary and Recommendations

1. To meet the estimated future demand, we anticipate that the current water supply of 15 lps (250 gpm) will have to be increased to 45 lps (675 gpm).

2. An analysis of a groundwater sample collected from LC-4 indicates that LC-4 may be contaminated with coliform bacteria from surface sources. To ensure the safety of the current water supply, Brown and Caldwell recommends that water samples be collected from LC-4 and analyzed for both total and fecal coliforms. If tests confirm that LC-4 is contaminated with coliforms, the well should be disinfected on a regular basis until a new well can be drilled.

3. Brown and Caldwell recommends re-drilling well LC-4 and installing 10-inch-diameter casing to increase production from this well. The new well should be screened from no higher than 25 meters (75 feet) bgs to prevent contamination from the surface.

4. This study investigated the deeper aquifer north of LC-4; our results indicate that the deeper aquifer in this area is not a source of significant source of groundwater supply. Therefore, future investigations should be focused to the south and east and in shallower aquifer zones down to 100 meters (300 feet) bgs. Due to the complex and heterogeneous nature of the underlying geology, we recommend drilling pilot wells to assess the hydrogeologic conditions before drilling and installing water supply wells. Brown and Caldwell recommends that additional water supply wells should be first drilled east and west of LC-4, along, and just north of the PanAmerican Highway as described above.

5. Conduct regular groundwater monitoring of the groundwater monitoring well network defined above and update the project database.

6. Form a cooperation to manage the groundwater resources of Limon de la Cerca and surrounding communities together with the Municipality of Choluteca. This cooperation will allow for more efficient and sustainable management of the underlying groundwater resource.

7. The geology and hydrogeology in the vicinity of Limon de la Cerca is complex and highly variable. Brown and Caldwell has established conceptual model of the geology and hydrogeology in the vicinity of Limon de la Cerca. As additional wells are drilled, and aquifer test data is acquired, this information should be incorporated in the existing knowledge base and the conceptual refined to develop a better understanding of the hydrogeology in the region.

8. The hydrogeologic conditions to the south and east, across the PanAmerican Highway look promising as a future water supply source; however, little information has been gathered about this area. A detailed hydrogeologic assessment should be performed in the area to the

south and east across the PanAmerican Highway to assess long-term future potential of the groundwater resource in this area.

9. A permitting system should be established for the drilling of new water supply wells in the region. The permits should require that the owner and/or driller of the well provide the municipality of Choluteca information about the depth, size, and yield of each well being drilled. This information should be input into the project database. The municipality should reserve the right to monitoring any permitted wells.

10. Once the new water distribution system and sewage systems have been are completed, and homes are connected to these systems, Brown and Caldwell estimates that water usage will increase by 400 percent. We recommend that the municipality work with FUNDEMUN and other NGO's to develop a water conservation plan.

11. Additional wells will need to be drilled to meet future water demands. We recommend that the municipality acquire land, or secure drilling rights for drilling these future wells. Brown and Caldwell recommends approximately 100 square meters of land will be required to drill and operate each new well.

APPENDIX A

Conceptual Model and Rational for Phase II Field Investigation

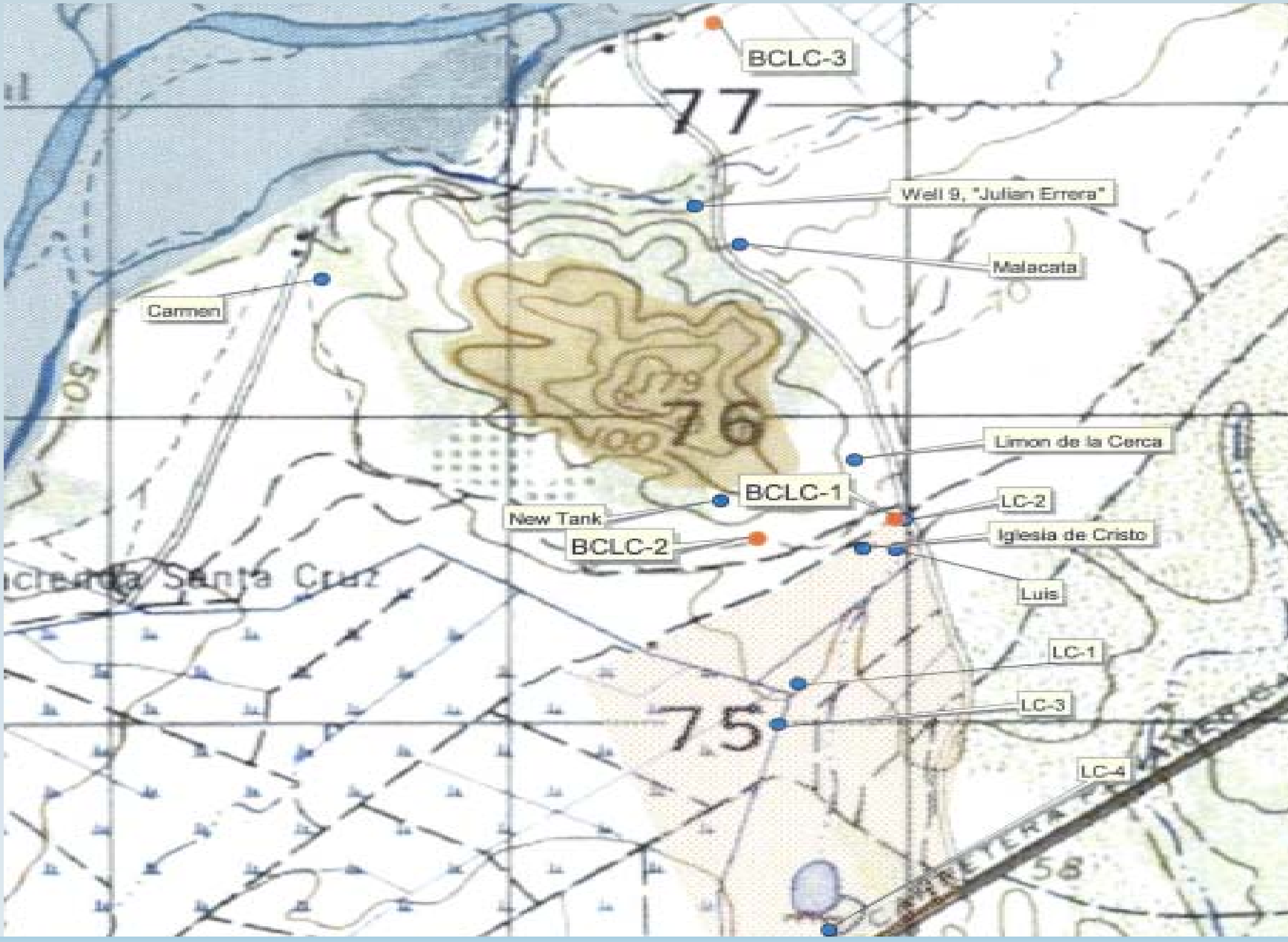
(Revised: February 2002)

Conceptual Model Update

Preliminary Groundwater Supply Recommendations

CONCEPTUAL MODEL AND RATIONALE FOR PHASE II FIELD INVESTIGATION

Muncipality of Choluteca - Limon de la Cerca, Republic of Honduras, C. A.



July 2001

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INTRODUCTION

This document represents the Phase I hydrogeological conceptual model for the Limón de la Cerca area. The conceptual model presents the results of the data review and the rational for the conduct of the Phase II field investigation. The project background, water resources and needs, setting, data gaps, and recommended areas for field investigation and activities are described.

BACKGROUND

The purpose of this project is to develop a water resources management plan for Limón de la Cerca to ensure sustainable water resources for municipal water supply. This project is funded by the US Agency for International Development (USAID).

Limón de la Cerca, also known as "Ciudad Nueva" and "Juan Benito Guevara," is located about 5 kilometers north of the municipality of Choluteca in the Department of Choluteca, along the Panamerican Highway. Limón de la Cerca is the historical name of a small village that exists along the Choluteca River. The subject of this study is the new resettlement community that has been developed over the last three years.

Various government and non-governmental organizations (NGOs) have been constructing several resettlement communities in this area, including Ciudad Nueva. The purpose of these communities is to provide housing for families that lost their dwellings due to the flooding caused by Hurricane Mitch in October 1998.

The community called Ciudad Nueva (or Limón de la Cerca) is currently included in the Ground Water Monitoring Studies. Ciudad Nueva is located on the north side of the Panamerican Highway. Ciudad Nueva has a planned capacity of 2,400 homes. The people per dwelling unit ranges from 5 to 11 people. Ciudad Nueva includes a school and medical clinic.

Located on the south side of the highway are the colonias of Satelite, Gracias a Cristo, and Marcelino. Marcelino has capacity for 620 homes. Currently 400 homes exist. The average household size is seven persons per dwelling unit. Several other colonias are located further away. While none of these colonias are fully developed at his time, they are developing rapidly. This study only addresses Ciudad Nueva.

Limón de la Cerca lies within the Choluteca River valley with the Choluteca River lying to the north and west. The relatively flat Choluteca valley extends for several kilometers to the north, east, and south, with the exception of a slight topographic high area interrupting the flat terrain about 1 kilometer to the south. This feature may be a volcanic remnant. There is a hill located on the north side of Ciudad Nueva. This area receives between 60 and 75 inches of precipitation per year.

EXISTING WATER RESOURCES

Limón de la Cerca relies on groundwater for all of its water supply. It is anticipated that reliance on groundwater for municipal water supply will increase as population growth continues in the future.

Five wells with 2-inch discharges are being used for water supply. The water distribution system provides water to several community collection points. All of the dwelling units will receive water directly once the water system construction is completed.

A masonry water storage tank is currently under construction on the hillside on the north side of Ciudad Nueva. A centralized sewer collection system is also under construction.

The water distribution system consists of one pressure zone and the water storage reservoir to the north that is under construction. In addition, there are several bladder type storage bags that are mounted on small-elevated platforms that are approximately 20 feet in height.

Water will be pumped directly from the wells to the new reservoir located to the north. From this reservoir, water under gravity flow will supply the community.

The majority of the water piping system consists of a looped network of 2, 3, and 4-inch water lines. The amount of water leakage from the piping system is not known, but is thought to be small due to the system being very new.

Each of the other nearby colonias has a separate water system that is not interconnected with the adjacent water systems. These colonias all utilize groundwater wells as their sole source of water supply. The wells supplying groundwater for these water systems are typically small wells that have 2-inch pipe discharges and a pumping capacity range from 30 gpm to 130 gpm. The same groundwater aquifer is used to supply all of these developing colonias.

The service area boundary of the municipality of Choluteca is located approximately 3 kilometers from the closest of the new resettlement communities, which is Marcelino. It is likely that Choluteca will assume management and operational responsibility for the water systems of these colonias at some time in the future. The Choluteca water system will probably be interconnected with the water systems that serve each of the colonias as infill development occurs in the vacant lands between the resettlement communities and the existing Choluteca water system. Choluteca utilizes groundwater from five wells for much of its water supply. Some of Choluteca's water supply comes from springs (600 gpm) and a river gallery (1,800 gpm). There are also 680 private wells in the area.

FUTURE WATER NEEDS

The future water needs for Ciudad Nueva have been estimated in a recent engineering study. These water demand projections will be verified through this study with the water production meters that have recently been installed on the existing wells as part of this project. Water demand projections and the resulting need for additional wells will be more precisely calculated later in this study.

RATIONAL FOR WATER RESOURCE EXPANSION

The objective is to locate sustainable groundwater supplies that can be economically utilized. The most economical groundwater supplies would be close to existing water system infrastructure with acceptable water quality and yield that meets anticipated supply needs.

GEOLOGICAL SETTING

Limón de la Cerca lies within the Choluteca River valley with the Choluteca River lying to the north and west. The relatively flat Choluteca valley extends for several kilometers to the north, east, and south, with the exception of isolated bedrock outcrops. The most prominent rock outcrop is located immediately to the north of Limón de la Cerca. Valley sediments are primarily comprised of quaternary deposits that have been divided into upper, middle and lower terraces (see Figure 1). The upper terrace represents the vast majority of the valley alluvial deposits on which Limón de le Cerca is located. The upper terrace is comprised of mudflows and alluvial deposits derived from the surrounding upland areas. Additionally, there is potential for isolated fluvial deposits within the upper terraces associated with historic drainages. The middle terraces, which are of limited extent, are found along the margins of the Holocene flood plain of the Choluteca River. These deposits are suspected to be fluvial in nature and were most likely deposited by the Choluteca River. The current Holocene sediment deposition by the Choluteca and Samplie rivers comprises the area classified as the lower terrace deposits. These deposits are located within the current flood plains of these drainages.

The alluvial valley deposits are bounded to the north and southeast by upland areas, which are comprised of volcanics of the Padre Miguel Group. The volcanic materials to the north have been primarily characterized as andesite and rhyolite. The volcanic materials to the south have been characterized as andesite and welded tuff. As indicated a number of rock outcrops have been observed within the Choluteca Valley. These outcrops are comprised of volcanic materials consistent with materials comprising the uplands.

Regional and local faulting has been documented in the Choluteca Valley (see Figure 1). A region strike-slip fault system is located approximately one kilometer to the north of the Choluteca River. The fault system trends to the northeast southwest and can be traced across the entire southeast portion of Honduras. This fault most likely controls the location of the Choluteca River. Other smaller northwest trending faults have also been observed in the Choluteca Valley. One of these northwest trending faults is believed to be located approximately 1.5 kilometers to the southwest of Limón de la Cerca.

The alluvial deposits range in thickness from 40 feet to 85 feet in the vicinity of Limón de la Cerca. These deposits have been described as interbedded clays, silts, and sands. A review of the available well logs indicated that sands are present within these units although, they appear to be limited in extent. Immediately to the north of Limón de la Cerca (approximately 0.4 kilometers) is a volcanic andesite outcrop. Which represents the bedrock materials that underlie the study area. Figure 2 presents a conceptual geologic cross-section illustrating the vertical distribution of geological units. Additional rain gauging and climatical stations were not necessary to successfully complete this study.

Vegetation and land use maps are not included in this report, as they are not considered appropriate at this time.

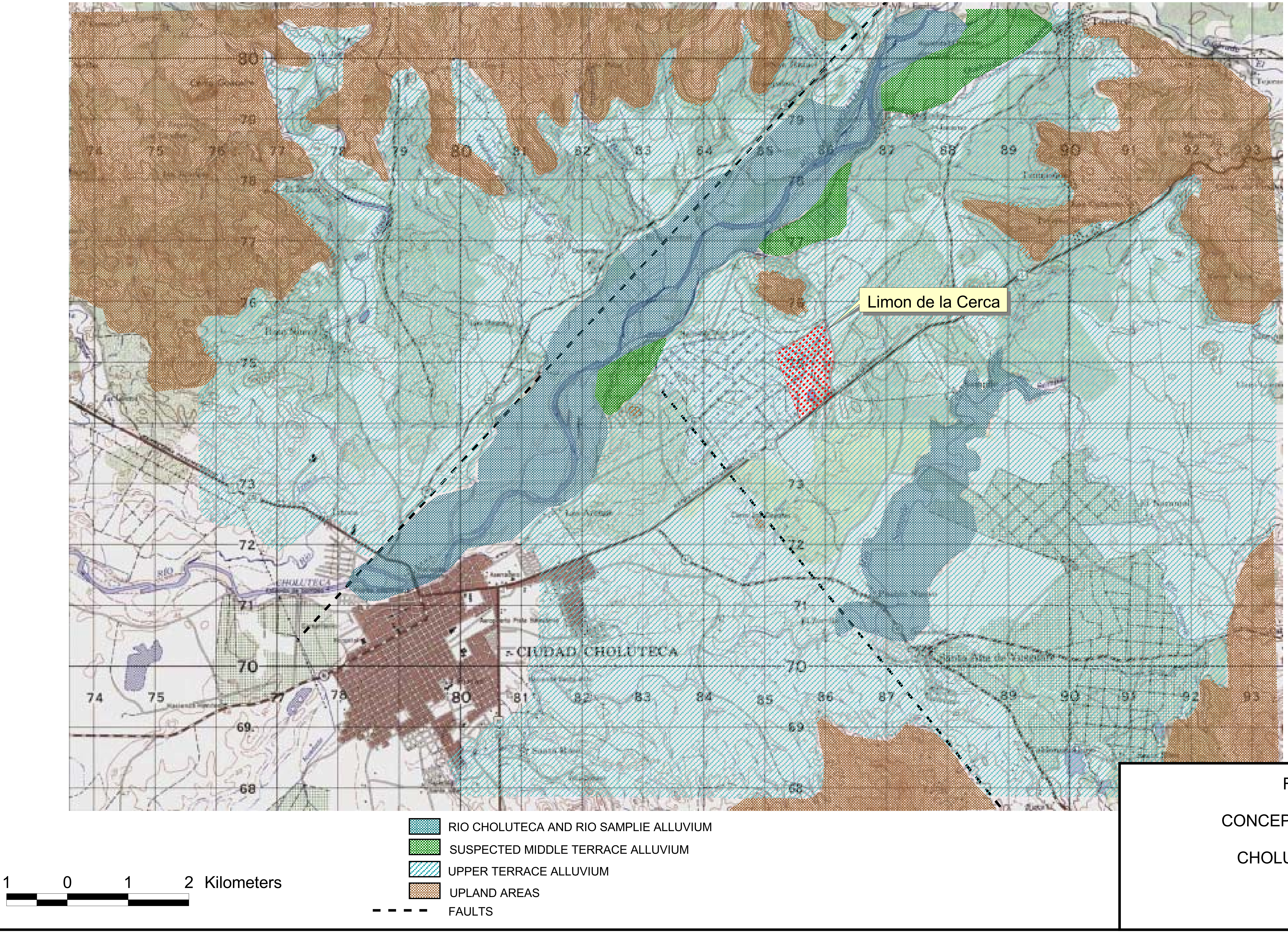


FIGURE 1

CONCEPTUAL GEOLOGY
OF THE
CHOLUTECA VALLEY

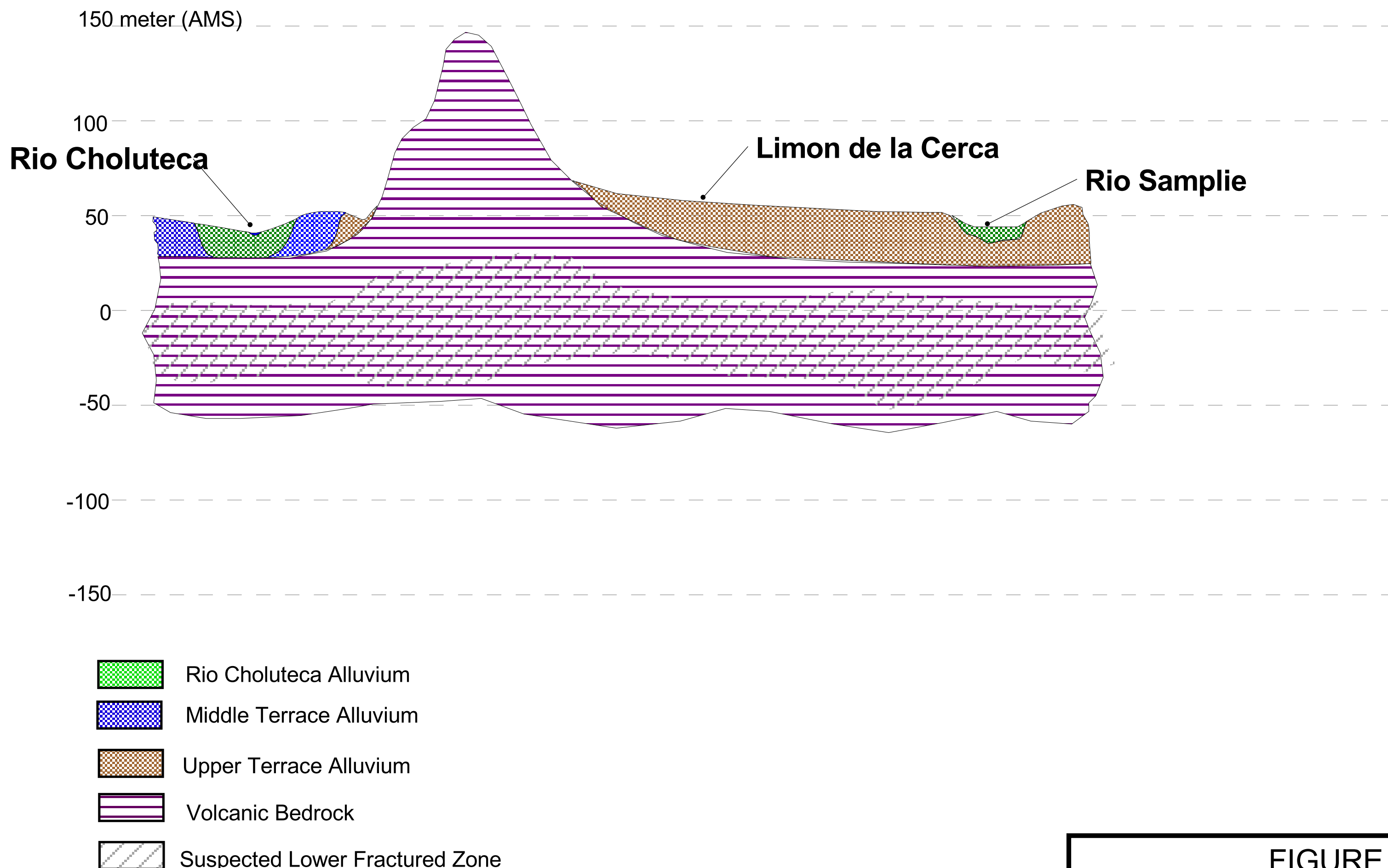


FIGURE 2

CONCEPTUAL GEOLOGIC CROSS-SECTION LIMON DE LA CERCA

Drawing not to scale.

HYDROGEOLOGICAL SETTING

The Choluteca Valley is bounded to the north and southwest by upland areas comprised of volcanic materials. These upland land areas serve as the major surface and groundwater recharge areas for the Choluteca Valley. Surface water infiltrates into the fracture networks of the uplands providing groundwater recharge to the valley bedrock and alluvial. Groundwater from the northern uplands general flows to the south and groundwater from the southern upland areas generally flows to the northwest. Once the groundwater from the upland areas enters the valley bedrock and sediments, groundwater flow will generally begin to move down valley and towards the Choluteca and Samplie rivers. Both of which serve as the major groundwater discharge points for the valley hydrologic system.

Within the valley, groundwater occurs in the valley bedrock and alluvial sediments. Based on review of the available well information, aquifers within the upper terrace deposits are limited in nature and are unable to produce sufficient supplies of groundwater. Currently two wells are screened within alluvial material at Limón de la Cerca (LC-1 and LC-3) (see Figure 3). Each of these wells produces less than 60 gpm. This is a consistent trend observed throughout the upper terrace deposits in the vicinity of Limón de la Cerca.

The middle and lower terrace deposits are associated with more recent deposition by the Choluteca and Sampile rivers. These deposits are suspected to be more laterally extensive and greater water production potential. Based on information obtained from local drillers, there is a water supply well located approximately 2.5 kilometers to the southeast of Limón de la Cerca. The well is believed to service the development located in that area. Based on the suspected location of this production well, it is believed that the well is screened within the alluvial materials associated with the Sampile River. Unconfirmed reports suggest that this well produces water in excess of 300 gpm. This unconfirmed information suggests that middle and lower terrace deposits can potentially produce sustainable groundwater supplies.

Currently two bedrock wells are serving Limón de la Cerca. Production well LC-4 is located in the southern portion of the community and screened to a depth of 200 feet. It also produces approximately 250 gpm, with estimated yields of 550 gpm (see Figure 3). The second well LC-2 located in the northeast portion of Limón de la Cerca. This well is screened to a depth of approximately 125 feet and produces approximately 80 gpm. Local drillers reported that they have also attempted to install bedrock production wells within the Choluteca Valley. Their experience suggests that, at least for the upper 100 to 200 feet of bedrock, water production in the bedrock is sporadic. This suggests that groundwater flow within the bedrock aquifer is either being produced for a deeper fracture system or a linear system of fractures that represents structural stress within the Choluteca Valley. A review of the early pumping test data collected from LC-4 indicated that the aquifer behaves as a porous medium. This supports the premise that a potential aerially extensive system of fractures may exist within the deeper bedrock system (see Figure 2).

EXISTING PRODUCTION WELLS

PROPOSED TEST WELLS

0.4 0 0.4 0.8 1.2 Kilometers

FIGURE 3

EXISTING AND PROPOSED WELL LOCATIONS

LIMON DE LA CERCA

RECOMMENDED AREAS FOR FIELD INVESTIGATION

Based on a review of the available data for Limón de la Cerca, the deep bedrock aquifer and middle/lower terrace deposits have been identified as having the highest probability of providing sustainable groundwater supplies. As a result, it is recommended that the deeper bedrock and the middle/lower terrace deposits be further investigated.

DATA GAPS

The Phase I data collection and evaluation has identified the following data gaps:

- Additional information is required to evaluate the deep bedrock aquifer for sustainable yields of groundwater.
- Additional information is required to evaluate the middle/lower terrace deposits for sustainable yields of groundwater.

RECOMMENDED FIELD ACTIVITIES

The field program for Limón de la Cerca outlined below was designed to evaluate deeper groundwater resources for the growing community as well as further define available groundwater resources in the Rio Choluteca alluvium.

Geophysical Surveys

A geophysical survey will be conducted to aid in the evaluation of the deep bedrock aquifer. The objective of the geophysical survey would identify potential linear fracture systems, if present, and to determine if the deep bedrock fracture system is laterally extensive. A refraction and reflection seismic survey will be conducted to evaluate the lower bedrock fracture system. Seismic methods rely on a contrast in acoustical properties between geologic materials to delineate boundaries such as the interface between overburden and bedrock, and variation within the subsurface (i.e., fractured zones at depth). Two seismic lines will be shot. The first line will be shot along the southern border of Limón de la Cerca, and the second will be shot along the southern border of Limón de la Cerca for a total line length of approximately 2 kilometers.

Additionally, a limited terrain conductivity survey will be conducted to identify potential sands and gravel associated with the middle terrace deposits. The terrain conductivity is based on electromagnetic (EM) methods. EM produces a primary field, which, on penetrating the ground, induces a voltage that causes a current to flow in a conducting subsurface. The subsurface current in turn creates a secondary EM field, which is measured by the receiver. The ratio of the secondary field to the primary field is proportional to the ground currents and therefore the ground conductivity. Variations or contrast in ground conductivity can be used to identify subsurface materials. Approximately, three survey lines, 200 meters in length, will be conducted in the vicinity of the proposed middle terrace test well location.

Down-hole geophysics will be conducted on each of the boreholes installed during this evaluation. The geophysical suite will include resistivity, spontaneous potential, gamma, caliper, and temperature.

Test and Monitoring Wells

We recommended that one test (BCLC-1) well and one monitoring well (BCLC-2) be installed to evaluate the deep bedrock aquifer (see Figure 3). The BCLC-1 will be located adjacent to LC-2 and will be drilled to an estimated depth of 500 feet. The monitoring well (BCLC-2) will be located approximately 350 meters to the west of the test well and approximately 150 meter to the south of the newly constructed water tank. It will be completed to the base of the fracture system identified in the test well. Each well will be completed with PVC surface casing that will be keyed approximately 5 feet into competent bedrock and then cement grouted to the surface.

We recommend the installation of one test well (BCLC-3) in the middle/lower terrace deposits. This test will be located approximately 1.6 kilometers to the north of LC-2 and will be drilled to the top of bedrock (approximately 100 feet). The test well will be completed as a PVC well. The screened interval will be selected based on the results of the lithologic description of the sediments and down-hole geophysics.

The borehole and well specifications are provided as an attachment.

Aquifer Tests

Step testing and recovery testing will be conducted on each newly installed test well to calculate specific capacity, well efficiency, and transmissivity. The step test will be conducted over a 6 to 8 hour period. Following the step tests the wells will be pumped at a constant rate for approximately 12 hours. During this testing draw-down, recovery data will be collected. The recovery data will be collected until the well has recovered to within 90 percent of the original static water level.

Additionally, a constant rate-pumping test will be conducted on the deep bedrock test well. The test will be conducted for a minimum of 48 hours. The test well will be pumped a sufficient rate to adequately stress the aquifer system as determined during the step testing. Draw-down will be monitored in the deep bedrock test well and the bedrock monitoring well. Additionally, pumpage from LC-2 and LC-4 will be monitored to account for external influences.

Water Quality Sampling

Each interval that is identified as yielding sufficient amount of groundwater will be tested for the follow parameters:

- Total dissolved solids
- Specific conductance
- pH
- CaCO3
- Acidity

- Alkalinity as $CaCO_3$
- Nitrate/Nitrite
- Coliform
- Chloride
- TAL metals (arsenic, barium, cadmium, chromium, fluoride iron, lead, manganese, mercury, nickel, selenium, silver, sodium, and zinc)

ANTICIPATED FIELD RESULTS

The anticipated field results are as follows:

- The installation of the bedrock will identify potential fracture systems within the deep bedrock aquifer.
- The surface geophysics will identify potential linear fractures that may exist in the vicinity of Limón de la Cerca. The surface geophysics will also determine the potential lateral extent of the deep bedrock fracture system.
- Deep bedrock aquifer testing will yield well specific capacity and aquifer transmissivity. The results will also provide insight in to whether the deep bedrock is behaving as porous medium equivalent.
- The installation of the middle terrace alluvial wells will identify potential production zones within this unit.
- Testing of the alluvial will yield well specific capacity and aquifer transmissivity.
- Identification of groundwater production zones of suitable groundwater quality.

CONCEPTUAL MODEL UPDATE

Limón de la Cerca, Honduras

December 26, 2001

1.0 INTRODUCTION

Brown and Caldwell is in the process of completing the field investigation portion of a water resource investigation for Limón de La Cerca. The purpose of the water resource study is to develop a management plan to ensure a sustainable water resource for current and future residents.

The original or "Old" Limón de la Cerca, a small agricultural village, is located along the eastern slope of a small topographic rise within the Choluteca River valley, just east of El Carmen. This water resources investigation addresses Ciudad Nueva, or the "New" Limón de la Cerca, the resettlement community was established for residents who lost their homes due to flooding during Hurricane Mitch in 1998. The New Limón de la Cerca is located along the north side of the Panamerican Highway, approximately 5-km northeast of Choluteca. For the purposes of this investigation, the entire area, which encompasses both the Old and the New communities, will be referred to as Limón de la Cerca.

Currently, the community of Nueva Limón de la Cerca consists of approximately 2,500 housing units to accommodate a population of approximately 13,500. Several health care, schools, churches and public safety building are located throughout the community. Other than grocery stores and several other small shops, no other industry or businesses exist in the area (Flores Molina, 1999).

Limón de la Cerca relies on groundwater for all of its water supply. It is anticipated that reliance on groundwater for municipal water supply will increase as population growth continues in the future. Five wells are currently used for water supply. Each well pumps water intermittently to fill 5,000-gallon storage tanks. The water is then released to several community collection points. A masonry water storage tank is currently under construction on the hillside on the north side of Ciudad Nueva. The new water distribution system will consist of one pressure zone. Water will be pumped directly from the wells to the new reservoir. Water under gravity flow, from this reservoir, will supply the community. Once complete, all of the dwelling units will receive water directly.

2.0 HYDROGEOLOGIC SETTING

Limón de la Cerca lies within the wide valley flood plain of the Choluteca River. The river is located to the north and west of the Limón de la Cerca. The valley is bound to the north and southwest by upland areas comprised of a variety of igneous rocks, including volcanic materials. The valley terrain is relatively flat, interrupted only by occasional low hills of volcanic or other bedrock material.

Honduras and most of Central America is situated in an area characterized by significant volcanic activity and structural deformation as a result of plate tectonics. From the coastline of El Salvador, to about 150 km inland, along the southern border of Honduras, the terrain represents the volcanic arc of the Cocos Plate subduction zone (Rogers, 2001). During the late Tertiary, plate subduction produced significant volcanic activity in the western and southern portion of the Honduras, resulting in thick (up to 2 km in some areas) deposits of ignimbrites and pyroclastics (as those of the uplands north and south of Limón de La Cerca). Continued uplift in this area caused rivers to rapidly downcut, creating meander channels into bedrock. Similarly, the north Honduras coastline delineates part of the strike-slip fault zone between the North American Plate and the Caribbean Plate (UTIG, 2001). This zone is represented by a series of northeast trending parallel transverse faults, which extend throughout the country. The fault located north of Choluteca is part of the Choluteca Lineament, a basement-cored structural feature. This fault system trends northeast-southwest and can be traced across the southeast portion of Honduras, and is believed to control the location of the Choluteca River. Other regional and local faults documented in the area include a series of northwest-southeast trending normal faults.

The Choluteca Valley is bounded to the north and southwest by rugged upland areas comprised of primarily of igneous rocks. These upland areas serve as major surface and groundwater recharge areas for the Choluteca Valley. Surface water infiltrates into the fracture networks of the igneous rocks that provide groundwater recharge to the valley alluvium and bedrock. Groundwater from the northern uplands generally flows to the south and groundwater from the southern upland areas generally flows to the northwest. Once the groundwater from the upland areas enters the valley alluvium and bedrock, flow will generally begin to move down valley, towards the Choluteca and Samplie rivers. Both of these rivers are major groundwater discharge points for the valley hydrologic system.

Within the valley, groundwater occurs in the bedrock and alluvium. Currently, two wells producing at least some percentage of groundwater from bedrock are serving Limón de la Cerca. Production well LC-4 is located in the southern portion of the community and is screened to a depth of 200 feet below ground surface (bgs). It reportedly produces 250 gallons per minute (gpm), with estimated yields in excess of 300 gpm. The second well, LC-2, is located in the northeast portion of Limón de la Cerca. This well is screened to a depth of approximately 125 feet and produces approximately 50 gpm. The volume of production attributed to bedrock is not clear.

Terraces consisting of Quaternary alluvial/fluvial deposits border the Choluteca River floodplain. These terraces have been divided into upper, middle, and lower units based on sediment type and age. The upper terrace is comprised of mud flow and alluvial deposits derived from surrounding upland areas. Based on review of the available well information, saturated zones within the upper alluvial terrace deposits are limited in nature and do not produce sufficient supplies of groundwater. Currently two wells are screened within alluvial material at Limón de la Cerca (LC-1 and LC-3). Each of these wells produces less than 60 gpm. This is apparently a consistent trend observed throughout the upper terrace deposits in the vicinity of Limón de la Cerca.

The middle terraces, of limited extent, are situated along the margins of the Choluteca River flood plain. These deposits are suspected to be fluvial in nature and were most likely deposited by the Choluteca River. The lower terrace deposits represent current Holocene fluvial deposits, and are situated within the river floodplain. Total thickness of the alluvial deposits is approximately 40 – 85 feet, reportedly underlain by volcanic rocks. Both of these are associated with more recent deposition by the Choluteca and Sampile rivers. These deposits are suspected to be limited in aerial extent, however, compared to the upper terrace deposits, may have greater potential as a groundwater resource in localized areas.

3.0 SUMMARY OF INITIAL CONCEPTUAL MODEL

Based on previous studies, interviews with local representatives, and a field reconnaissance, the initial conceptual model was developed based on the understanding that the fractured igneous rocks of the upland areas serve as the major source of groundwater recharge to the alluvium and bedrock. Precipitation recharge to the northern and southern highlands would flow through bedrock and sediments, towards the valley, and ultimately discharge to the Choluteca River. Based on information from local drilling companies, favorable groundwater production occurs from the alluvial deposits, and from a deeper bedrock fracture system. Available information indicated that production from the terrace deposits is limited and of insufficient quantities to provide for the needs of the community

4.0 FIELD INVESTIGATION

Brown and Caldwell investigations to date have included a geophysical survey, water quality survey, and installation of three monitoring wells.

4.1 Geophysical Survey

In order to better understand the regional geology and locate potential groundwater horizons, Terra-Dynamics conducted a geophysical survey to collect subsurface data along three high-resolution seismic refraction lines. The primary objective of this study was to define the bedrock surface in areas where knowledge of the depth to bedrock was limited, and to analyze subsurface topography to evaluate the potential for buried bedrock valleys containing thick sand and gravel deposits.

Additionally, one seismic reflection survey was conducted along the eastern border of the community. Information from this line was collected to further map the bedrock from north to south to determine the presence of potential deeper groundwater producing structures.

Results from the geophysical survey indicate that three layers are detectable using seismic refraction. The first layer is interpreted to be a very fine grained, unconsolidated clay layer. The second layer is similar to the first, and is interpreted to be a slightly more consolidated layer with the same composition as the first. The third layer is interpreted to be bedrock, moderately consolidated. The seismic survey was capable of clearly differentiating the contrast between these horizons and was used to map the alluvial stratigraphy, and the nature of the bedrock surface. Because the seismic velocity of the bedrock remained relatively constant across the three survey lines, it is believed the upper bedrock lithology and physical characteristics are quite similar within the study area.

4.2 Drilling and Installation of Wells

Two open borehole test wells (BCLC-1, BCLC-2) and one screened well (BCLC-3) were installed as part of the BC field investigation. Test wells BCLC-1 and BCLC-2 were located along the northern border of the new community, approximately 500 meters and 200 meters respectively, from the new water storage tank. BCLC-1 is located adjacent to existing production well LC-2. Test holes BCLC-1 and BCLC-2 were drilled to depths of 475 and 500 feet respectively (reportedly the deepest borehole penetrations in the area) to explore the production the lower bedrock. Well BCLC-3 is located approximately 1.5 kilometers to the northeast of the community and was installed to explore the production potential of the Rio Choluteca alluvium.

Drill cuttings and video indicate test well BCLC-1 encountered sandy clay with gravel from the surface to a depth of 40 feet bgs; interpreted to be primarily alluvial in origin. From 40 feet to 240 feet bgs, conglomerate was observed. The conglomerate consists of poorly sorted, moderately cemented, subrounded to angular clasts ranging in size from pebbles to cobbles. A thin horizon of basalt was observed at a depth of 105 to 110 feet bgs. Down hole video images indicate the conglomerate to be lightly to moderately fractured, with calcite filling much of the fracture voids. From 240 to 475 feet bgs, moderately to highly fractured welded volcanic tuff was observed.

Test hole BCLC-2 encountered gravelly sand and silt to a depth of 50 feet bgs. From 50 to 335 feet bgs, lightly to moderately fractured welded volcanic tuff was observed. From 335 to 500 feet bgs, moderately fractured basalt was observed.

The test hole for the BCLC-3 well was drilled to a depth of 150 feet bgs to explore the production potential of the Choluteca River valley alluvium. Inspection of drill cuttings indicates that from the surface to 80 feet in depth, alternating layers of unconsolidated silty-, sandy- and clayey gravels were observed. These layers are interpreted to be representative of the terrace deposits. Below 80 feet bgs, highly weathered and fractured basalt was penetrated down to the bottom of the test hole. A permanent monitoring well was installed at this location, to a depth 150 feet bgs.

4.3 Water Quality Survey

Additional surveys of existing wells performed by Brown and Caldwell have found that water quality within the area of Limón de la Cerca is generally good. However, existing well LC-4, located in the southern portion of the community, has elevated levels of coliform bacteria. The upper portion of the bedrock, located below 70 feet, is believed to be the significant water-producing zone. Because the well screen interval is from 40 to 200 feet below grade, contaminated groundwater from the shallow alluvial units are probably impacting water quality. The average TDS concentration from the existing water supply wells is approximately 195 ppm (Jordanlab, 2001). The WHO does not currently have a recommended guideline for TDS (WHO, 1996).

4.4 Aquifer Testing

Short term and long-term aquifer tests were performed on selected wells to evaluate the water resource development potential. A step draw-down test was performed on bedrock test well BCLC-1. Results indicated that the well can be long term tested at a rate of 90 gpm. Due to marginal yields, very limited tests were conducted in wells BCLC-2 and BCLC-3. A step draw-down test was also performed on bedrock well BCLC-2. The test indicated that yields from this well would likely be less than 35 gpm. Alluvial well BCLC-3 was also step tested and indicated that well yields would likely be less than 20 gpm.

Currently, a 72- hour aquifer test is being performed on Well BCLC-1. BCLC-1 was selected for the long-term pumping test because it was the highest yielding well of the two newly installed bedrock wells. During the test, the well is maintained a flow rate of 90 gpm, with a draw-down of approximately 40 to 50 meters. Preliminary results indicated that BCLC-1 would yield approximately 60 to 80 gpm. However, long-term pumping rates are difficult to project accurately due to the complexity of the surrounding geology/hydrology.

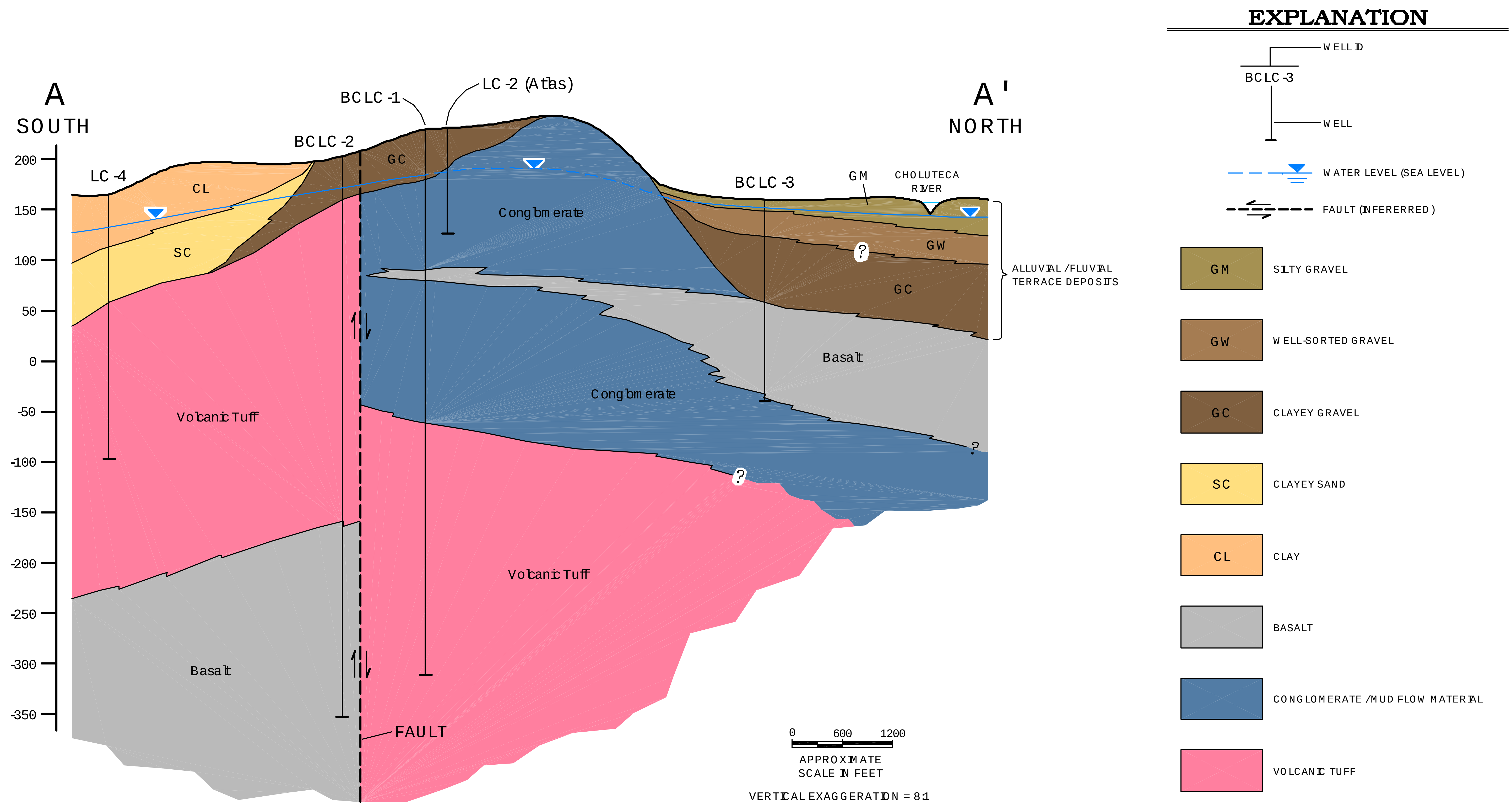
5.0 UPDATED CONCEPTUAL MODEL

Based on the results of the geophysical survey and information from the well installation, a geologic profile was constructed from south to north, from the lithology described at existing production well LC-4, and new boreholes BCLC-2, BCLC-1, existing production well LC-2, and BCLC-3 (Figure A-1). Existing production well LC-4 is located along the southern boundary of Limón de la Cerca, along the Panamerican Highway. According to SERPE drill records, lithology at well LC-4 consists of clay from the surface to 40 feet bgs, and sand and minor amounts of clay from 40 to 80 feet bgs. This material is interpreted to be alluvial and fluvial valley-fill deposits. Below, volcanic rock was described from 80 to 200 feet bgs (SERPE drill report, date unknown). The lithology of LC-2 is reported as alluvium from 0-40 feet bgs and volcanic rock from 40 to 125 feet bgs.

The lithology described in the profile is consistent with the complex geologic history of periods of uplift, volcanism, faulting and erosion in the area. The thick section of conglomerate observed at test well BCLC-1 is interpreted to be an ancient valley-filling mudflow/lahar-type deposit from volcanic eruptions from the surrounding highlands. Following uplift and faulting, the more erosion resistant section of conglomerate remained as a topographic high in comparison to surrounding less resistant terrain. Between BCLC-1 and BCLC-2, a fault is inferred, with BCLC-2 located on the upthrown side. The welded volcanic tuff and basalt observed at test well BCLC-2 are likely representative of the thick layer of pyroclastic and igneous rocks observed in this area. Fault movement resulted in the juxtaposition of welded volcanic tuff against the thick section of conglomerate at BCLC-1. Both units are fractured, but it is uncertain whether groundwater flow through the fractures is in communication across the fault line. To the north, the geology between BCLC-1 and BCLC-3 is interpreted to be representative of the alluvial terrace deposits of the Choluteca River, which has cut a broad floodplain into the volcanic materials seen in the surrounding uplands.

6.0 SUMMARY OF FIELD INVESTIGATION FINDINGS

Preliminary results of the field investigation indicate that marginal water supplies are present within the upper 500 feet of bedrock, in the vicinity of the newly constructed water supply tank. However, due to the complexity of the area geology and hydrogeology, the sustainability of the resource is uncertain. Available data indicate that groundwater fracture flow in the volcanic bedrock plays an important role in groundwater recharge. However, the presence of faults and discontinuous lithologic units may be acting to impede recharge flow pathways.



BROWN AND CALDWELL

Figure A-1
CROSS-SECTION
LIMON DE LA CERCA, HONDURAS

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This uncertainty was demonstrated by comparing the results from BCLC-1 and BCLC-2. Preliminary results from well BCLC-1 indicated that sustainable production rates would be in the range of 60 to 80 gpm. Aquifer tests for well BCLC-2, located approximately 300 yards west-southwest from BCLC-2, indicate the well is projected to yield less than 15 gpm. Furthermore, during the aquifer test at BCLC-1, no groundwater response was observed in BCLC-2. These results demonstrate the uncertainty and complexity of the hydrogeologic system, which limits the ability to accurately predict production yields.

Preliminary results of the field investigation also indicate that the alluvial deposits located on the margins of the Choluteca River flood plain may not yield sufficient supplies for municipal purposes. Existing well LC-4, located along the southern portion of Limón de la Cerca, has an estimated sustainable yield of approximately 300 gpm. This well is screened within the lower portion of the alluvium and the upper portion of the bedrock. A review of available data indicates that the majority of the water is produced from fractures within the upper portion of the bedrock. As indicated earlier, the majority of water was produced from the lower portion of the bedrock in BCLC-1 and BCLC-2. The differences in production demonstrate the heterogeneity of the aquifer system. This localized fracture system in the vicinity of LC-4 has the potential for sufficient supplies for municipal purposes.

The approach of the field investigation was designed to gain a better understanding of both bedrock fracture flow as well as to identify groundwater production zones within the alluvium. Once those zones were identified, aquifer testing would be conducted in order to assess well specific capacity and aquifer transmissivity.

Preliminary results of this investigation indicate that marginal water supplies are present within the upper 500 feet of bedrock, in the vicinity of the newly constructed water supply tank. However, due to the complexity of the geology/hydrogeology, the sustainability of the resource is uncertain. Available data indicate that fracture flow in the volcanic bedrock plays an important role in groundwater recharge. However, the presence of faults and complex geology may hinder recharge flow pathways. This uncertainty was demonstrated by comparing the results from BCLC-1 and BCLC-2. Preliminary results from BCLC-1 indicated that sustainable rates would be in the range of 60 to 80 gpm. BCLC-2, which is located approximately 300 yard from BCLC-2, is projected to yield less than 15 gpm. Furthermore, during the aquifer test at BCLC-1, no response was observed in BCLC-2. These results demonstrate the uncertainty and complexity of the hydrogeologic system, which limits the ability to accurately predict production yields.

Preliminary results of this investigation also indicate that the alluvial deposit located on the margins of the Rio Choluteca flood plan do not yield sufficient supplies for municipal purposes. Existing well LC-4 located in the southern portion of the community has an estimated sustainable yield of approximately 300 gpm. This well is screened within the lower portion the alluvium and the upper portion of the bedrock. A review of the available data indicates that the bulk of the water is been produced from fractures within the upper portion of the bedrock. BCLC-1 and BCLC-2, where the bulk of the water was produced from the lower portion of the bedrock, demonstrated the heterogeneity of the aquifer system. This localized fracture system in the vicinity of LC-4 has the potential for sufficient supplies for municipal purposes.

7.0 PRELIMINARY WATER SUPPLY RECOMMENDATIONS

There is a limited potential to expand the current water supply in the vicinity of the newly installed storage tank to meet existing water demands and that required for short-term (5 to 8 years) growth (projected to be approximately 500 gpm). This additional 500 gpm is necessary for maximum day demand and is in addition to the existing water supply. The existing and newly -installed wells in the area produce approximately 80 to 100 gpm. Due the variability of the estimated well yields and the uncertainty associated with hydrogeology, it is unlikely that any one well will meet the projected production needs. It is recommended that a series of production wells be installed to meet the accumulative total of approximately 300 gpm. Based on the current understanding of the hydrogeology, it is also recommended that these wells be installed in vicinity of BCLC-1, east of the inferred northwest-southeast trending fault. It is estimated that the production needs may be met by the installation of an additional 2 to 5 bedrock wells. The wells will be installed and tested as single events. The results of which will be used to determine the need for additional wells. It should be noted that there is a risk that after these wells are installed, the production needs may not be met due to the complexity of the hydrogeology.

It is unlikely that long-term water supplies to meet projected growth can be developed from area in the vicinity of the storage tank. Increasing water demand will likely need to be addressed with alternative sources of potable water. A key element in the success of alternative water supply development will be use the existing bedrock well LC-4, which is located in the southern portion of the community. This well has the potential to yield approximately 300 gpm. However, water from this well will require treatment and replacement of the well with the proper screen construction interval, one that is protected from contamination from shallow groundwater. Additionally, investigation in the southern portion of the community may result in additional water supplies associated with the LC-4 bedrock production zone.

8.0 REFERENCES

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PRELIMINARY GROUNDWATER SUPPLY RECOMMENDATIONS

Limón de la Cerca, Honduras

December 26, 2001

201 North Civic Drive
Walnut Creek, California 94596
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BROWN AND CALDWELL

December 26, 2001

Ing. Mauricio Cruz
Agencia de los Estados Unidos Para el Desarrollo Internacional
Avenida La Paz
Tegucigalpa, Honduras

21143-410

Subject: Preliminary Groundwater Supply Recommendations
Limon de la Cerca, Honduras

Dear Ing. Cruz:

As you requested, Brown and Caldwell has prepared this letter describing our preliminary recommendations for water supply wells in the Limon de la Cerca development area. Our review of CH2M-Hill's current design of the water supply system for Limon de la Cerca indicates that the design calls for the extraction of groundwater from existing groundwater supply well LC-4 (also referred to as Pozo B), located south of the Limon de la Cerca development and just north of the Pan American Highway, and two additional wells referred to as Pozo A and Pozo C. As discussed in our December 6, 2001 project meeting, we understand that you are requesting that Brown and Caldwell make preliminary recommendations for meeting short term potable water demand requirements of up to 250 gallons per minute (gpm) for the Limon de la Cerca development. Based on our preliminary results, it is our opinion that well LC-4, with some modifications, can most likely meet the short term demands of 250 gpm. A more detailed discussion is presented below.

Well LC-4

We understand that groundwater supply well LC-4 is currently the primary groundwater supply well for the Limon de la Cerca development area. Pertinent information regarding LC-4 is as follows:

- LC-4 is constructed with 8-inch-diameter casing and extends to a depth of approximately 200 feet below ground surface (bgs);

- LC-4 is screened from approximately 40 to 200 feet bgs, and has the potential to produce up to 300 gallons per minute (gpm);

- Coliform bacteria have been detected in the samples collected from well LC-4, indicating that the well has been contaminated from nearby domestic waste water sources.

Based on the above information and our preliminary analysis of the data we have collected, it appears that groundwater supply well LC-4 has the potential to yield up to 300 gpm and can meet short term demand for the Limon de la Cerca development. However, Brown and Caldwell recommends that LC-4 be re-drilled to approximately 300 feet bgs and reamed to a diameter that can accommodate 10-inch-diameter casing. After completing the new well, Brown and Caldwell recommends that a 72-hour pump test be conducted to more accurately determine the maximum sustainable yield from this new well. In addition, to reduce the risk of contamination from surface domestic waste water sources, the well should be screened from the top of hard bedrock (a depth of around 70 feet bgs), rather than 40 feet bgs as the current well is screened. Brown and Caldwell recommends that the space between the well casing and the wall of the borehole (the annular space) shall be effectively sealed from ground surface to top of the hard bedrock, or just above the screened interval. The sealing material shall consist of neat cement grout or sand-cement grout. The neat cement grout shall be composed of one sack of Portland cement (43 kg) combined with 17 to 25 liters of clean water. If sand-cement grout is used, it shall be composed of no more than two parts by weight of sand and one part of Portland cement with 17 to 25 liters clean water per sack of cement.

Additional Wells

If additional water is required, Brown and Caldwell recommends that up to two additional wells be drilled; the locations of these additional wells are shown on Figure 1, (attached). The second well should be drilled approximately 750 to 1000 feet to the southwest of LC-4, along the Pan American Highway, near the proposed location of proposed Pozo A (Figure 1). Brown and Caldwell recommends that this well be drilled to approximately 300 feet bgs, be constructed with 10-inch-diameter casing, and screened from 60 or 70 feet bgs to total depth as described above for the LC-4 replacement well; again, a 72-hour pump test should be performed. However, field conditions and pump test results may warrant different construction specifications. Please be aware that although Brown and Caldwell believes it is likely that this well will produce between 150 and 300 gpm, it is possible that the highly variable geologic and hydrogeologic conditions may result in a much lower sustainable yield, making this well impractical for use as a water supply well. If necessary, Brown and Caldwell recommends that a third water supply well be drilled approximately 750 to 1000 feet to the northeast of LC-4, also along the Pan American Highway. This proposed well location is approximately 500 feet south and east of proposed Pozo C (Figure 1). Preliminary construction recommendations for the third well are the same as the second well described above.

Brown and Caldwell will provide more detailed information regarding proposed future drilling locations and construction specifications in the Groundwater Resource Management Plan we are developing for the Limon de la Cerca development area. We hope this information is sufficient to meet your current needs. Please feel free to contact me or Mr. Greg Christians of Brown and Caldwell at (615) 255-2288 in the U.S. if you would like more information or have any questions regarding this letter.

Very truly yours,

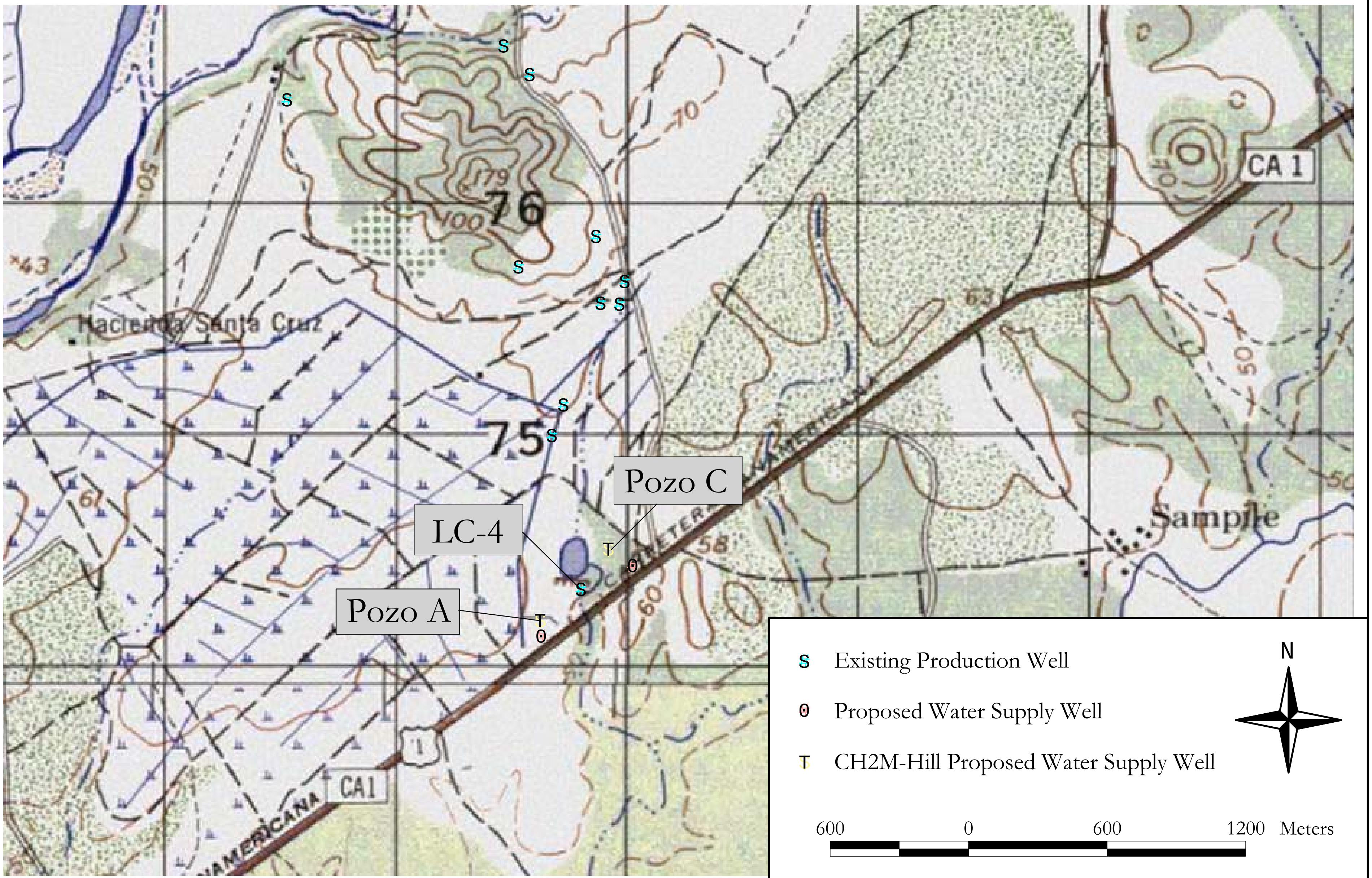
BROWN AND CALDWELL

Jeff Nelson

Jeff Nelson
Project Director

JN:gm

Attachment



BROWN AND CALDWELL

DATE	SITE	
12/26/2001	Limon de la Cerca, Honduras	FIGURE 1
PROJECT	TITLE	
21143	Proposed Water Supply Wells	

APPENDIX B

Seismic Refraction and Reflection Survey Results

Seismic Refraction and Reflection Survey Results Limon De Cerca, Honduras

Prepared for:

Brown and Caldwell
201 North Civic Drive, Suite 15
Walnut Creek, CA 94596-3864301 USA

Prepared by:

Terra-Dynamics Consulting Inc.
155 Portage Road
Lewiston, NY 14092
(716) 754-9439

September, 2001

TDC

TDC **Terra-Dynamics Consulting, Inc.**

155 Portage Road, Lewiston, NY 14092

September 7, 2001

Mr. Jeff Nelson
Principal-in-Charge
Brown and Caldwell
201 North Civic Drive, Suite 15
Walnut Creek, CA 94596-3864

Re: Seismic Refraction and Reflection Results, Limon De Cerca, Honduras
USAID Geophysical Surveys, Honduras,
Brown and Caldwell Contract 522-C-00.0100287-00

Dear Mr. Nelson:

1.0 INTRODUCTION

1.1 BACKGROUND

Brown and Caldwell were contracted by USAID to help locate and install water wells for the village of Limon De Cerca. The village is located about 5 km south east of Chuleteca along the Trans-America Highway. Brown and Caldwell in turn has contracted Terra-Dynamics Consulting, Inc. to help map the topography of the bedrock of the area using refraction and reflection seismic techniques to assist in the development of a more comprehensive geological model of the area.

1.2 OBJECTIVES

In order to better understand the regional geology and locate potential groundwater targets, Terra-Dynamics collected three high resolution seismic refraction lines during late July and early August of 2001. The primary objective of this study was to define the bedrock surface in areas where well control of the depth to bedrock was limited. In addition, seismic reflection data were acquired along one line to assist in the potential definition of bedrock structure.

1.3 LOCATION

Seismic acquisition was conducted over three lines, each approximately 1000 m long on the east, south and west sides of the Limon De Cerca site. Refer to Figure 1.

Line 01-01 was acquired from south to north along the shoulder of a rural road on the western most side of the village. The line started 20 m from the Trans-America Highway and continued north for 960 m.

Line 01-02 originated at the beginning of line 01-01 and ran perpendicular to line 01-0. This line was approximately parallel to the Trans-America Highway and intersected with Line 01-03 at station 681 of Line 01-02 and 651 of Line 01-03 . It is 1160 m long.

Line 01-03 ran parallel to the far eastern edge of the prospect for 1200 m and originated about 15 m to the east of the test well. This line ran along a rural road until a bend in the road where the line continued straight cross country to Line 01-02.

2.0 METHODOLOGY

2.1 SEISMIC METHODS

Seismic methods utilizes seismic energy that returns to the ground surface after travelling along refracted or reflected ray paths, and is typically used for locating interfaces of different acoustic impedances (products of velocity and density contrasts). The seismic energy can be generated by any number of sources, including a shotgun blast, a weight-drop (i.e. sledge hammer or EWG), a vibrator, or an explosive charge. The energy is used to generate the seismic pulse necessary to propagate through a geological medium. The resulting ground motion is detected at the geophones and digitally recorded by the seismograph. The most common method of acquiring shallow seismic reflection data is using Common-Depth-Point (CDP) continuous profiling (Figure 2). The recorded travel times and source-receiver geometry are processed to determine the depth to the geological interface of interest.

2.2 DATA ACQUISITION

Field equipment included a 14 pound sledge hammer and a 12 gauge energy source, 48 channel water-tight cables, Mark Product 14 Hz, single phone geophones, and an OYO DAS-1 24 bit (48 channel) engineering seismograph. The geometry utilized for the reflection spreads was 48 geophones spaced at 2 meter intervals. The seismograph was located between channels 24 and 25 allowing for 24 channels to be on either side of the seismograph for a maximum offset distance of 96 m. With this layout, both forward and reverse shots were obtained simultaneously. After all shots were taken on one spread, the back 24 geophones were moved ahead to become the forward stations of the next spread (Figure 3). This procedure continued until the line was completed. Using these overlapping spreads, a continuous profile of the bedrock surface was possible.

In total the survey consisted of 2 refraction lines, and one refraction/reflection line (Figure 1). The lines were locate in an attempt to delineate potential bedrock valleys and map the topography of the underlying bedrock.

Initial field preparation involved chaining and surveying the lines. Chaining involves marking individual station locations on the ground. These stations are used during acquisition to indicate receiver and shotpoint locations. Surveying is completed to accurately determine the surface position and the elevation differences of individual stations along the line. This information is used for processing. Final line preparation, when using a 12 gauge energy source, involved hand auguring 0.5 m deep holes (7.5 cm diameter) with a post hole auger.

Figure 4 shows the set-up of the seismic equipment. Figure 5 depicts a sledge hammer used for the refraction profiles. Overall field conditions were good throughout the project with little adverse noise and good filed access. Weather conditions were favourable for seismic acquisition with clear skies and light to medium winds. Figure 6 depicts the 12 gauge energy source used for the reflection/refraction profile.

2.3 DATA PROCESSING

Before interpreting seismic data, it is necessary to perform a series of processing steps after the raw data is down-loaded and reformatted from the seismograph. The processing techniques address near-surface effects such as ground coupling and statics, lateral velocity variations and image enhancements. In addition, advanced processing techniques applied to the data set include deconvolution, scaling and residual static analysis, and structural modelling to enhance velocity and static analysis. The steps involved in processing are summarized in a flow chart (Figure 7) and are briefly described as follows:

Step 1, Geometry
This step involved creating a database file that contains all information related to shot positions, shot depths, geophone spacing, shot elevations and any other acquisition parameters.

Step 2, Data quality control & First Break Interpretation (FBI)
After the geometries are applied the data is input into an interactive program designed to analyse geometry accuracy and edit bad traces and reversed geophones. At this stage, FBI, an interactive slope-intercept refraction analysis program, is used to perform preliminary velocity and depth calculations. FBI allows the user to directly view the shot record in its proper relative spatial location and assess data quality (i.e. strength of first breaks, dead traces). With a sloping line the velocity of the first arrivals on a shot record can be approximated thus calculating depth estimates to each layer characterized by differing velocities (Figure 8). The generalized reciprocal method is used to correct for near surface delays and/or statics. This step is the final step in the analysis of refraction data.

Step 3, Scaling, Deconvolution, & Trace Gathers
After edits and refraction analysis, the data is scaled to correct for energy losses as a function of time from the shot, followed by a surface-consistent root-mean-square amplitude correction. A deconvolution operator is applied, in order to whiten the frequency spectrum of the data for a more balanced picture of the reflectivity sequence.

The data are then gathered into common-depth point (CDP) bins by assigning each trace

to a gather corresponding to the midpoint between shot and receiver locations. At this time common receiver gathers are also created.
Normal moveout correction removes the effects of differing source-receiver offsets and a sub-surface common-midpoint stack yields a geological like profile in time. It is important to realize the data are presented in time and variable velocities will effect the transformation to depth. Processing velocities help to identify approximate depths of reflection events.

Step 4. Velocity and Static Analysis
The common shot and receiver gathers are used to create surface stacks to analyse surface-consistent residual statics, while the CDP gathers are used for velocity analysis and final output stacks. At this point in the processing stream, a loop of velocity analysis, followed by surface stacks for static analysis and a CDP stack, will simultaneously resolve the best velocity function and statics. This loop typically requires 2 or 3 iterations before converging. Generally the convergence is determined by comparing the results of each loop on the CDP stack.

Step 5. CDP Model & Post Stack Enhancement
After determining the best CDP stack, a final first break mute, to remove unwanted refraction's is chosen by examining the velocity corrected common offset stacks. An inside, or surgical, mute may also be applied to remove low velocity ground roll or air blasts. A model CDP stack, including the final velocities and statics and a post-stack noise reduction filter, is used as a trim stack for the final section. Each trace in a given CDP gather is compared with the corresponding model stack, and weighted by the cross-correlation value before computing the final trim stack. This step aids in removing the frequency lowering effect inherent in the stacking process.

Finally, a post-stack image enhancing process such as migration and/or noise reduction filter is applied, and a final display is created.

It is important to note that data quality is a key element to successful interpretation. Some uncertainty in depth will arise if data is noisy or first breaks are weak. This will cause inaccuracies in determining crossover times, velocities, and ultimately depths.

3.0 RESULTS

Within this area three layers were detectable using seismic refraction. The first layer is interpreted to be a very fine grained, unconsolidated clay layer. The second layer is similar to the first and is interpreted to be a slightly more consolidated layer with the same composition as the first. Due to the similarity in velocity of layers one and two, it was difficult to consistently pick each slope without picking some first breaks of the other. Since these to layers were sometimes difficult to distinguish, the interface is marked by a thin line on the refraction cross sections. The third layer is bedrock and is interpreted to be moderately lithophied and 'soft'. The seismic survey was capable of clearly detecting the contrast between these layers and was used to map the overburden stratigraphy and the nature of the bedrock surface. Since the velocity of the bedrock remained relatively constant across the three lines, there is little reason to believe that there is any lateral lithologic changes in the first layer bedrock.

A description of each seismic refraction profile completed for this study is presented below.

3.1 DESCRIPTION OF SEISMIC PROFILES

The seismic profile lines are attached in the pockets at the back of the report.

Refraction Line #01-01

Line 01-01 started 20 m north of the Trans America Highway in the south west corner of the prospect. The first station was 101 and the last station was 580. The line length is 960 m. Acquisition conditions were not ideal; construction of sewers and local traffic caused a moderate amount of uncontrollable noise adversely effecting the ability to accurately pick the onset time of the first arrivals. Rain in the evenings left field conditions slightly muddy and affected the sledge hammer's effectiveness as an impulse source.

Data quality on this line was moderate. It was sometimes difficult to distinguish the transition between the first and second layers. The cross-over from the overburden to bedrock layer was easily distinguished. Analysis of the refraction data indicates an average first layer velocity of approximately 400 m/s but at times it was as slow as 350 m/s and as fast as 500 m/s. Layer 2 velocities averaged approximately 900 m/s and sometimes were very close layer 1 velocities. This indicates layer one is very similar in lithology to layer two and it is therefore marked on the cross section as a thin line. The calculated velocity for the bedrock surface from the refraction data ranges from 2500 m/s to 3200 m/s. The range of this velocity is attributed to the quality of the bedrock first break picks as well as the composition of the bedrock material. The bedrock topography is characterized by an undulating surface which is dipping very slightly to the south. Since the velocity changes were gradual and small, there is little evidence to indicate that there is any lithology change in the bedrock along this line such as fracturing or weathering.

There was one area where a thin low velocity zone was detected between stations 180 to 210 within the overburden. This may indicate a thin unconsolidated lense of sand. Further investigation of this area is required to delineate this feature.

Refraction Line # 01-02

Line 01-02 started 20 m north of the Trans America Highway in the south west corner of the prospect. This line travelled perpendicular to line 01-01 and parallel to the Trans-America highway. Data quality on this line was better than line 01-01 because the line was cross country and extraneous road noise was minimal. The first station is 101 and the last station on the line is 623. The length of this line is 1048 m. The first and second layers were at times difficult to distinguish because their velocities are quite similar. During acquisition the winds were light and the skies were clear. It rained in the evenings causing some areas to be muddy and the sledge hammer to not produce as strong an impulse over these areas. The surface elevation was slightly hilly.

Similar to line 01-01 the cross-over from overburden to bedrock was easy to determine but the similarities between layers 1 and 2 made them more difficult. Analysis of the refraction data indicates an average first layer velocity of approximately 750 m/s +/- 100 m/s which is consistent with fine, dry, clay. Layer two averaged approximately 900 m/s +/- 100 m/s. The calculated velocity for the bedrock surface from the refraction data is approximately 2500 m/s on average. The bedrock is slightly undulating and there is indication of a shallow bedrock valley between stations 411 and 511 which is about 25 m deep and 200 m across. Since the velocity of the bedrock remains relatively constant there is little reason to believe there is any lateral changes in the bedrock from east to west.

Line # 01-03

Refraction

Line 01-03 started 15 m to the east of the test well and travelled south towards the Trans -America highway. This line is parallel to line 01-01 and perpendicular to line 01-02. The data on this line was gathered using a 12 gauge buffalo gun every two stations. Data quality on this line was better than line 01-01 and 01-02 construction was farther away. Since it was shot on every other station there were twice as many data points to choose from. The first station is 101 and the last station 681. During acquisition the winds were light and the skies were clear. The surface elevation was fairly flat.

Refraction data quality on this line was good. Similar to the other lines the cross-over from overburden to bedrock was easy to determine but the similarities between layers 1 and 2 made distinguish the change between them more difficult. Analysis of the refraction data indicates an average first layer velocity of approximately 500 m/s with variations of up to 100 m/s. Layer two averaged approximately 875 m/s with variations of about 100 m/s. This is consistent with a sandy clay layer. The calculated velocity for the bedrock surface from the refraction data is approximately 2500 m/s with it increasing slightly towards the south. The bedrock is slightly undulating and gets shallower to the south. Since the velocity of the bedrock remains relatively constant there is little reason to believe there is a lithologic change from north to south.

Reflection

The reflection data quality on this line was moderate to good with poor sections between stations 101 and 185 and 535 and 585 do to vehicular noise and drilling. The cross over from layer one to layer two is virtually undetectable using seismic reflection techniques, last station on the line is 623. The length of this line is 1048 m. The first and second layers were at times difficult to distinguish because their velocities are quite similar. During acquisition the winds were light and the skies were clear. It rained in the evenings causing some areas to be muddy and the sledge hammer to not produce as strong an impulse over these areas. The surface elevation was slightly hilly.

Similar to line 01-01 the cross-over from overburden to bedrock was easy to determine but the similarities between layers 1 and 2 made them more difficult. Analysis of the refraction data indicates an average first layer velocity of approximately 750 m/s +/- 100 m/s which is consistent with fine, dry, clay. Layer two averaged approximately 900 m/s +/- 100 m/s. The calculated velocity for the bedrock surface from the refraction data is approximately 2500 m/s on average. The bedrock is slightly undulating and there is indication of a shallow bedrock valley between stations 411 and 511 which is about 25 m deep and 200 m across. Since the velocity of the bedrock remains relatively constant there is little reason to believe there is any lateral changes in the bedrock from east to west.

Line # 01-03

Refraction

Line 01-03 started 15 m to the east of the test well and travelled south towards the Trans -America highway. This line is parallel to line 01-01 and perpendicular to line 01-02. The data on this line was gathered using a 12 gauge buffalo gun every two stations. Data quality on this line was better than line 01-01 and 01-02 construction was farther away. Since it was shot on every other station there were twice as many data points to choose from. The first station is 101 and the last station 681. During acquisition the winds were light and the skies were clear. The surface elevation was fairly flat.

Refraction data quality on this line was good. Similar to the other lines the cross-over from overburden to bedrock was easy to determine but the similarities between layers 1 and 2 made distinguish the change between them more difficult. Analysis of the refraction data indicates an average first layer velocity of approximately 500 m/s with variations of up to 100 m/s. Layer two averaged approximately 875 m/s with variations of about 100 m/s. This is consistent with a sandy clay layer. The calculated velocity for the bedrock surface from the refraction data is approximately 2500 m/s with it increasing slightly towards the south. The bedrock is slightly undulating and gets shallower to the south. Since the velocity of the bedrock remains relatively constant there is little reason to believe there is a lithologic change from north to south.

Reflection

The reflection data quality on this line was moderate to good with poor sections between stations 101 and 185 and 535 and 585 do to vehicular noise and drilling. The cross over from layer one to layer two is virtually undetectable using seismic reflection techniques, substantiating the idea that these to layers are very similar. The overburden / bedrock interface is easily detectable and shows up as the first dark line between 80 and 110 ms. The second dark line may indicate an increase in density with depth or second bedrock layer. There is strong evidence of a secondary interface between stations 365 and 425 at 140 to 150 ms range which is equivalent to depths of about 160 m. This interface may be a much harder volcanic rock below the first softer bedrock layer. There is also evidence of this layer between stations 215 and 255 at depths of 140 ms or 160 m. This bedrock layer is quite inconsistent which may indicate fracturing, or large variations in topography. It appears that this layer is deepest between stations 325 and 435 and rises towards the ends of the lines. Further investigation is required before any final analysis is made on this layer.

4.0 KEY FINDINGS

This investigation has illustrated that the use of refraction acquisition is an effective means of characterizing the first layer bedrock topography in the Limon De Cerca area. The use of a sledge hammer and the 12 gauge buffalo gun as a seismic source provided adequate data quality for refraction profiling. A larger source, such as dynamite, would provide for better seismic reflection resolution within the bedrock.

5.0 LIMITATIONS

There are some inherent ambiguities involved in seismic data collection. These ambiguities can be represented by summing the percentage of potential variations involved with each factor affecting the data. For this site, the following factors and their associated values are:

Elevation (+/-)1% + Distance (+/-)3% + Time Picks (+/-)3% + Velocity Estimate (+/-)8% = **Depth Estimate (+/-)15%**

Therefore a depth of 20 m will mean: 20 m +/- 3 m

The confidence in each profile increases with each line. During acquisition, line 01-01 had a large amount of uncontrollable noise and the ground was soft, therefore, picking exactly the first movement of the geophones was more difficult. There were also areas along line 01-01 were there appears to be thin lense of slower velocity material, such as sand, which has made picking first breaks in this area more difficult.

Line 01-02 had good data quality and confidence in this profile is greater than profile 01-01.

Line 01-03 refraction data are of good quality. It matches very nicely with the reflection data and therefore there is a large amount of confidence in this profile. The reflection data gathered was adequate for the job however, for better quality data, a larger source such as explosives would have been preferable, with a larger geophone offset and more data channels.

We trust that the information contained in this report is sufficient for your present needs. If you have any questions, please do not hesitate to contact our office at 716-754-9439.

Yours truly,

TERRA-DYNAMICS CONSULTING, INC.

David D. Slaine, P.G.
Principal

Attachments: Figures and Seismic Profile Lines

FIGURES

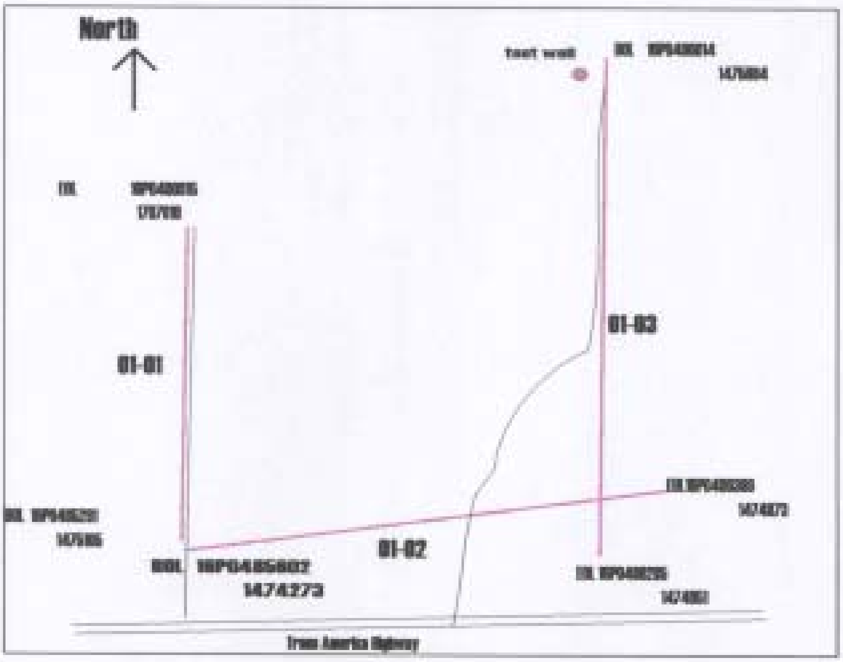


Figure 1. Location of Seismic Lines, Designated 01-01, 01-02, 01-03

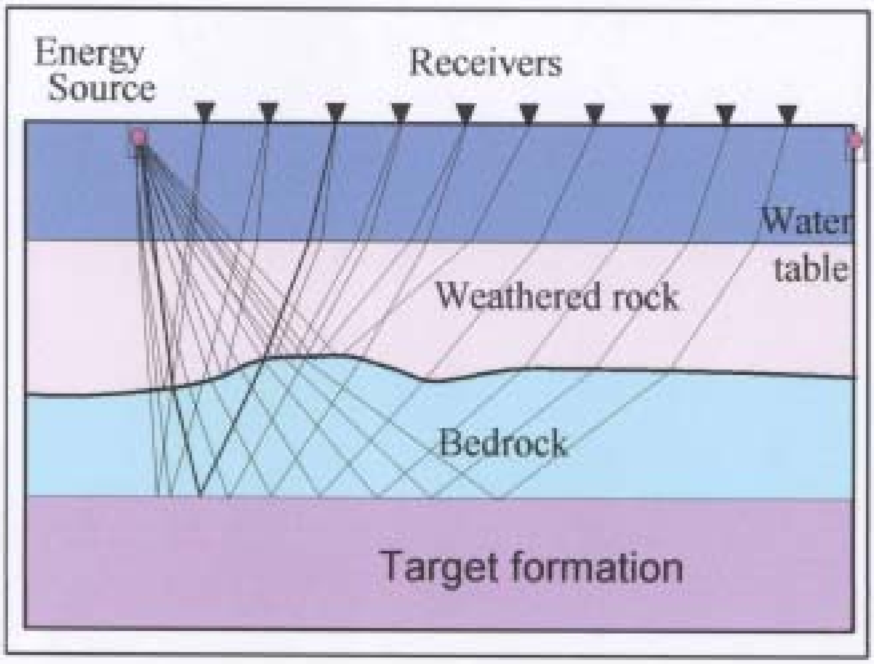


Figure 2. Diagram Illustrating the Principles of Common Depth Point Profiling

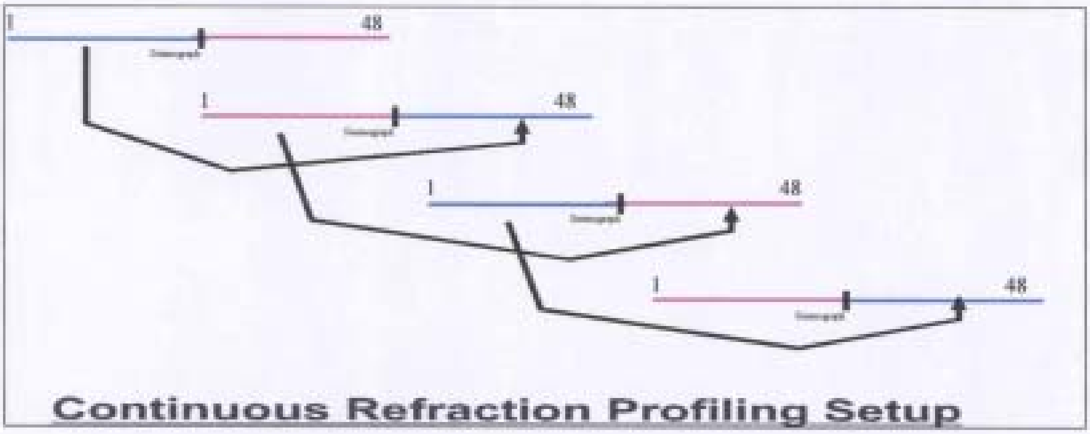


Figure 3. Diagram Illustrating the Method of Continuous Refraction Profiling.

Figure 4. Seismic Equipment During Set-up.

Figure 5. Sledge Hammer as a Seismic Source With Attached Trigger

Figure 6. Photograph Showing the In-hole 12 Gauge Shotgun Acoustical Seismic Source

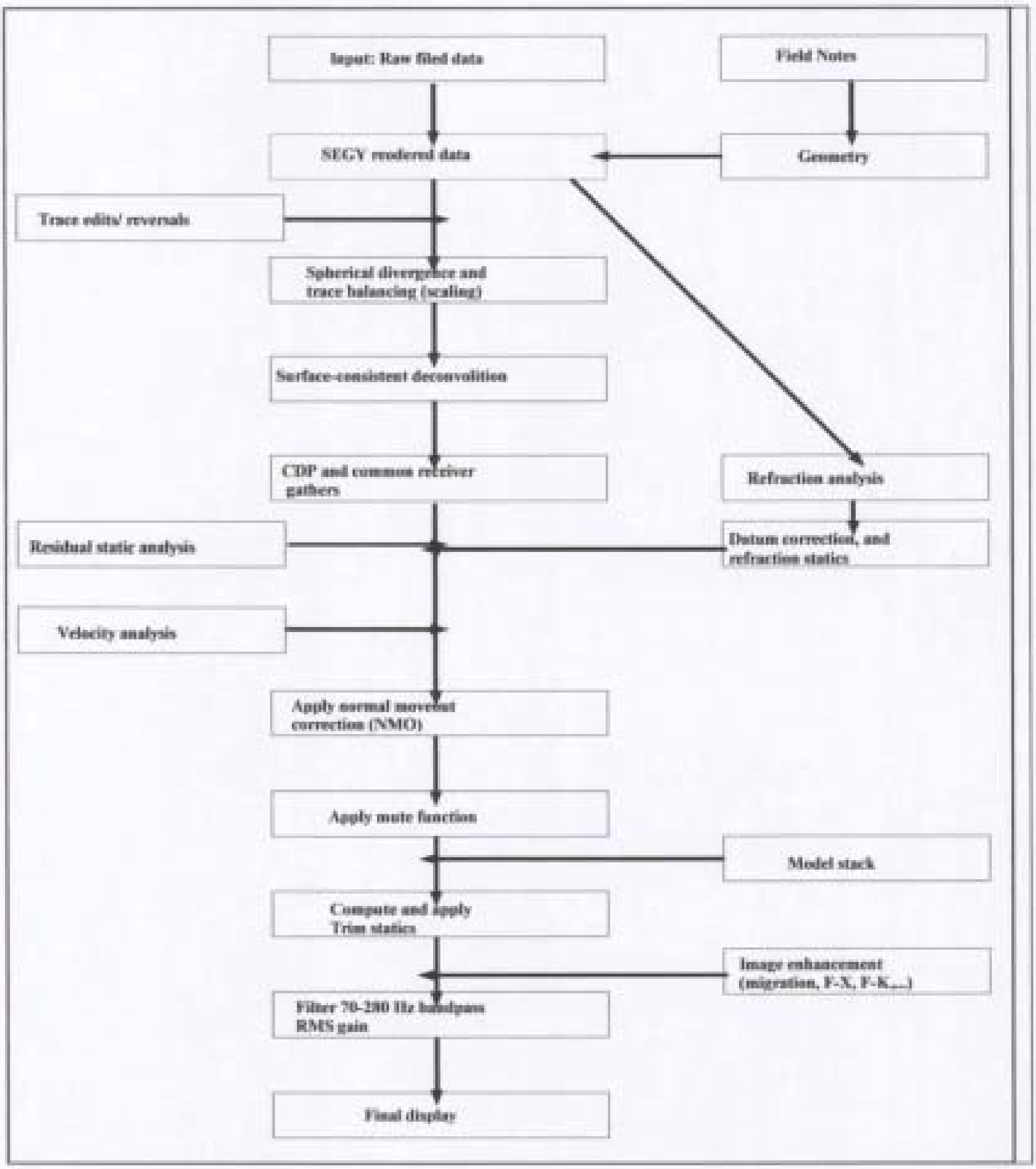


Figure 7. Flowchart Illustrating the Different Stages Involved in Reflection Processing

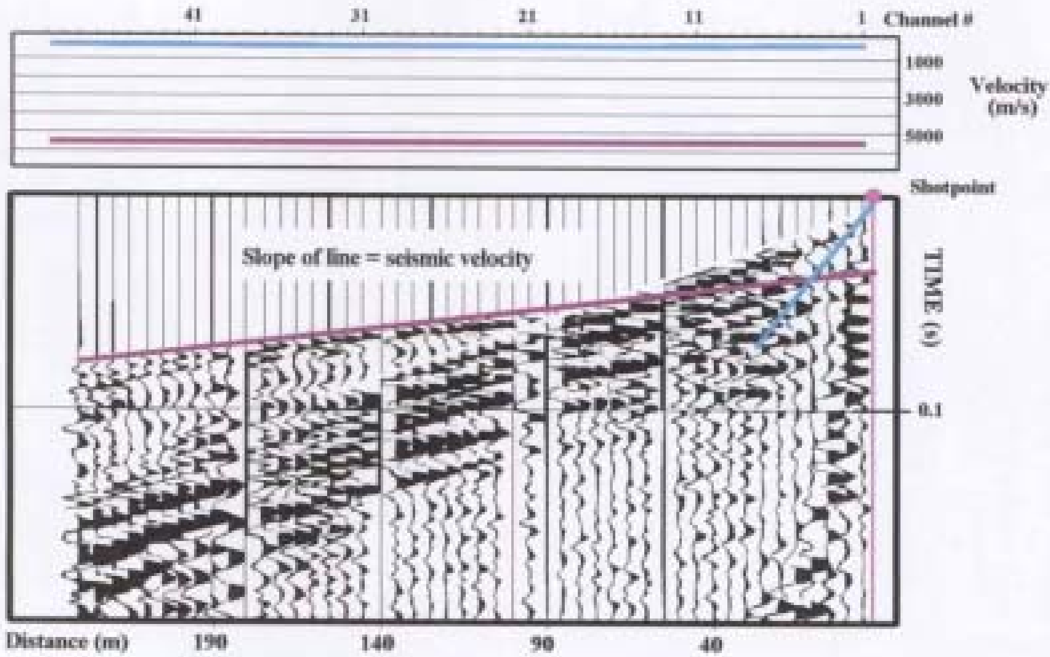
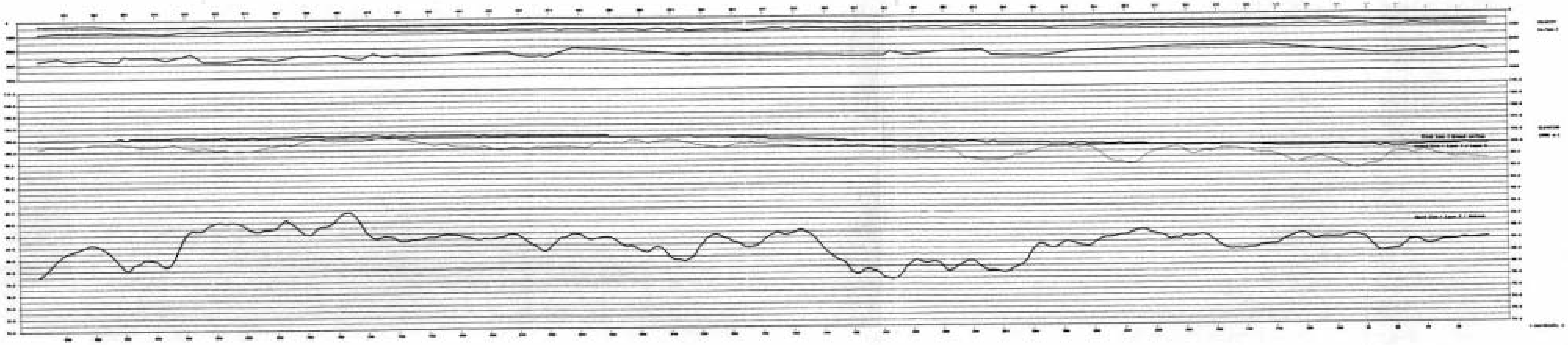


Figure 8 Reflection Shot Record Showing Three Different Velocities



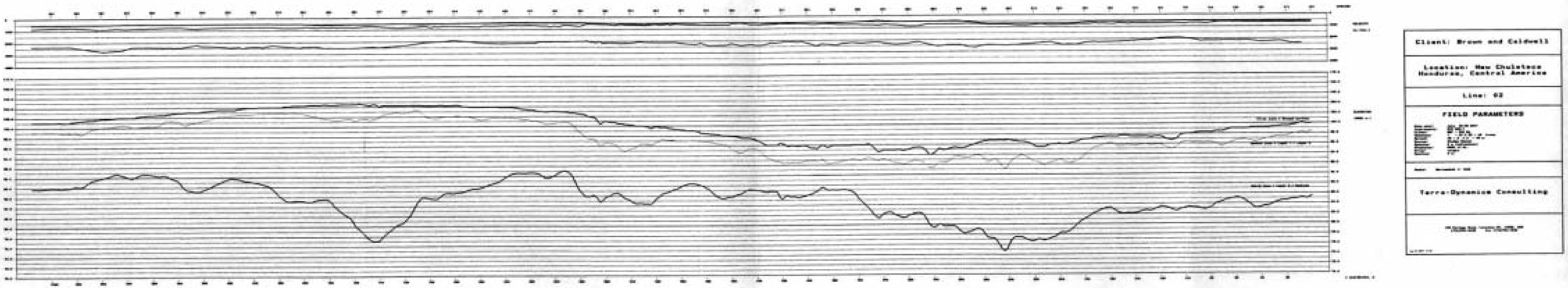
Client: Brown and Caldwell

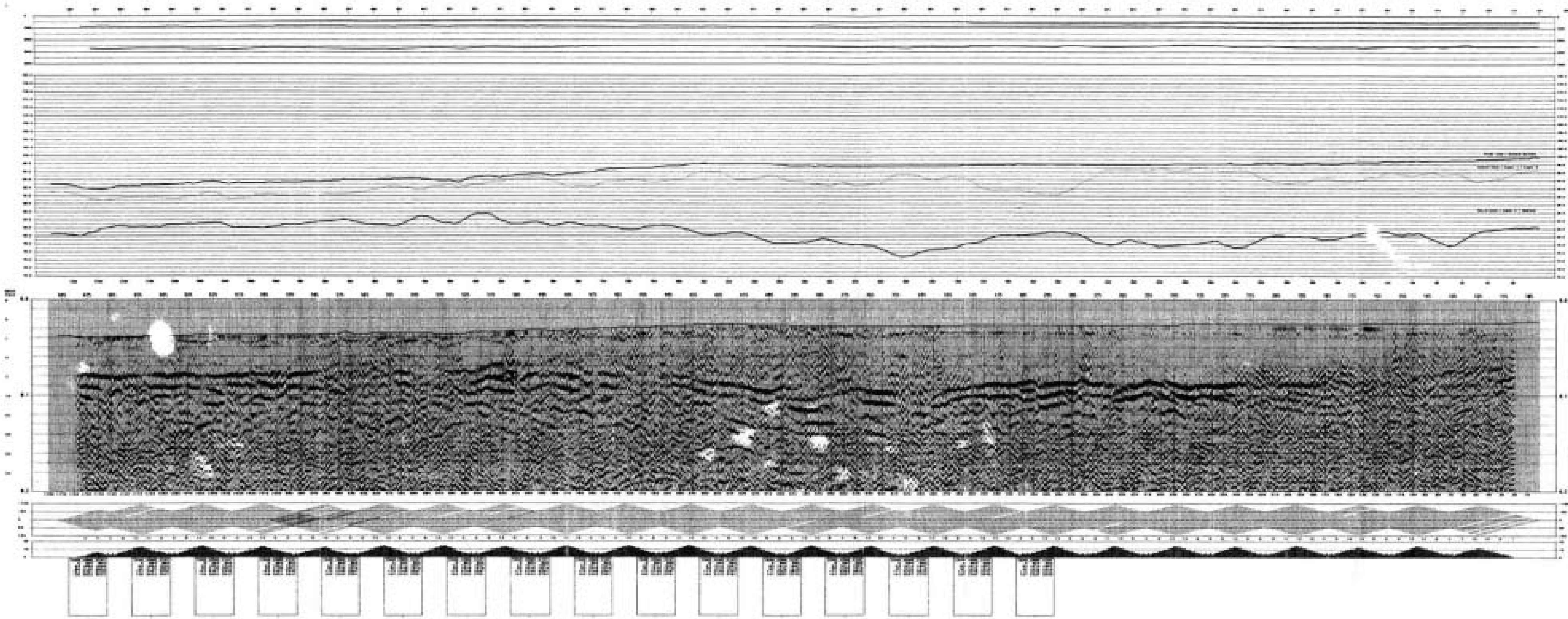
**Location: New Choluteca
Honduras, Central America**

Line: 01

FIELD PARAMETERS

Terra Dynamics Consulting


Client: Brown and Caldwell
Location: New Choluteca
Honduras, Central America
Line: 02
FIELD PARAMETERS
Terra-Dynamics Consulting



Client: Brown and Caldwell

Location: New Choluteca Honduras, Central America

Line: 03

FIELD PARAMETERS

Terra-Dynamics Consulting

APPENDIX C

Phase II Field Investigation Results

PHASE II FIELD INVESTIGATION RESULTS

Limón de la Cerca, Honduras

June 2002

1.0 INTRODUCTION

As part of Contract Number 522-C-00-01-00287-00, Phase 2 between United States Agency for International Development (USAID) and Brown and Caldwell three wells were installed and tested in Limón de la Cerca. Work performed included installation of exploratory boreholes, downhole geophysical logs, downhole video logs, construction of wells in exploratory boreholes, development of wells, and performance of step tests and pump tests. This report provides details on the installation and testing of these wells. Evauation of, and conclusions from, the data generated from this work are discussed in the Final Report produced under Phase 5 of this contract.

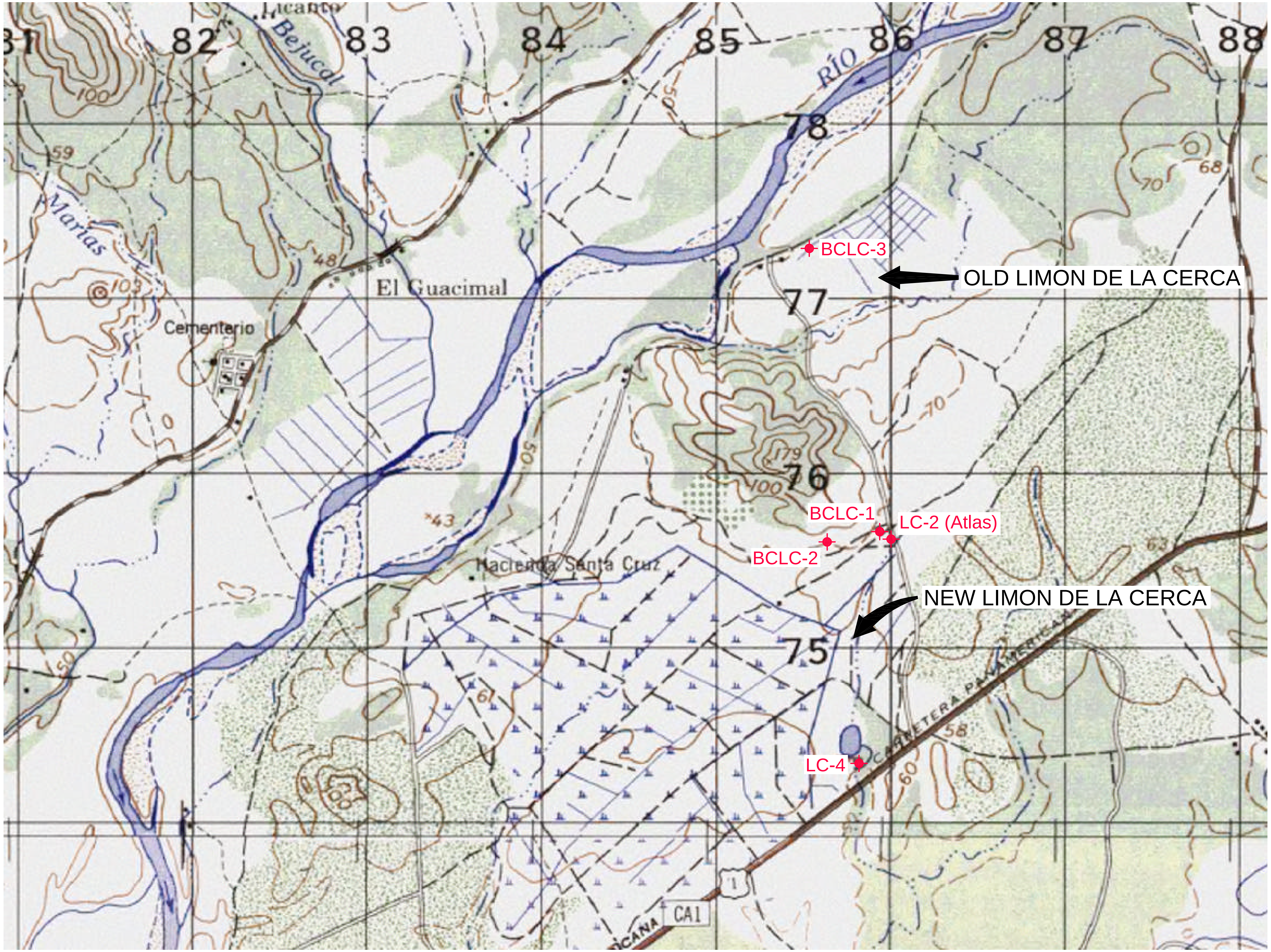
The wells installed are named BCLC-1, BCLC-2, and BCLC-3. Figure C-1 shows their location. The technical rationale for the location of each well was provided to USAID in the document "Conceptual Model for Limón de Cerca" and the technical procedures for conducting the work were detailed in the document "Technical Procedure for Phase II Field Investigation Boreholes and Wells For Limón de la Cerca". The construction of the wells is summarized in Table C-1. The details of the work performed during the exploration, drilling, well construction and testing of each well are presented in the following sections.

Table C-1. Summary of Well Construction

Name of well	Total depth of borehole, ft, bgs	Total depth of well, ft, bgs	Date well completed
BCLC-1	475	443	8/15/2001
BCLC-2	500	479	10/20/2001
BCLC-3	155	150	9/7/2001

2.0 EXPLORATORY BOREHOLES

At each location an exploratory borehole was drilled first after which the borehole was converted into a well. Drilling is illustrated below. Borehole BCLC-3 was converted to a test/observation well. Borehole BCLC-1 was equipped with a 6-inch PVC casing and screen. Borehole BCLC-2 was equiped with a 8-inch PVC casing. All boreholes were installed by Serviciós de Perforacion Drilling S. de R. L. de C. V. (SERPE) of Tegucigalpa, Honduras, C.A.. Details of borehole completion are provided in Table C-2. Completions of the boreholes were overseen by both Brown and Caldwell and staff employed with Asesores Técnicos en Ingeniería y Ciencias Ambientales S. de R. L. (ATICA).



EXPLANATION

BCLC-1 WELL LOCATION

BROWN AND CALDWELL

Figure C-1

WELL LOCATION MAP

LIMON DE LA CERCA, HONDURAS

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Table C-2. Borehole Completion Details

Well ID.	BCLC-1	BCLC-2	BCLC-3
Name of Driller	SERPE	SERPE	SERPE
Date started	7/24/2001	9/14/2001	8/21/2001
Date Completed	8/15/2001	10/20/2001	9/7/2001
Drilling Equipment	Gardner Denver 15W	Gardner Denver 15W	Gardner Denver 15W
Drilling Technique	Mud rotary through alluvium (55'). Air rotary with foam through 475'.	Mud rotary through alluvium (60'). Air rotary with foam through 500'.	Mud rotary
Drilling Fluid	air with foam	air with foam	mud
Drill bit and size	8 7/8-inch	8 7/8-inch	8 7/8-inch
Total Borehole Depth (ft, bgs)	475	500	155
Geophysical Company	Brown and Caldwell	not applicable	Brown and Caldwell
Date Geophysical Completed	8/22/2001	not applicable	8/29/2001

Figure C-2. Mud Rotary at BCLC-1

Water used for drilling was obtained from the Choluteca River. Drilling was planned to be conducted continuously but occasional mechanical problems with the drilling equipment and access problems caused by wet weather resulted in delays of approximately four and a half days. An example of the mud rotary drill rig is shown in Figure C-2 and a summary of the drilling delays is provided below.

- August 6, 2001 – One full day lost due to the drilling crew not mobilizing to the site.
- August 7, 2001 – One half day delay due to break down of water supply truck.
- September 10, 11, 12 – Three days delay for repair of access road to rig (at BCLC-3) which was damaged by heavy rainfall.

3.0 LITHOLOGIC LOGGING

A lithologic log of the drill cuttings was prepared describing the stratigraphy penetrated throughout the borehole. The information for this log came from drill cuttings collected every 10 feet. Cuttings were collected from the mud or foam exiting the well head and perserved by placing in plastic trays designed for this use. To develop descriptions of the stratigraphy the entire length of borehole cuttings was evaluated. Lithology is described for each borehole in the lithologic logs included as Figure C-3 through Figure C-5 of this report.

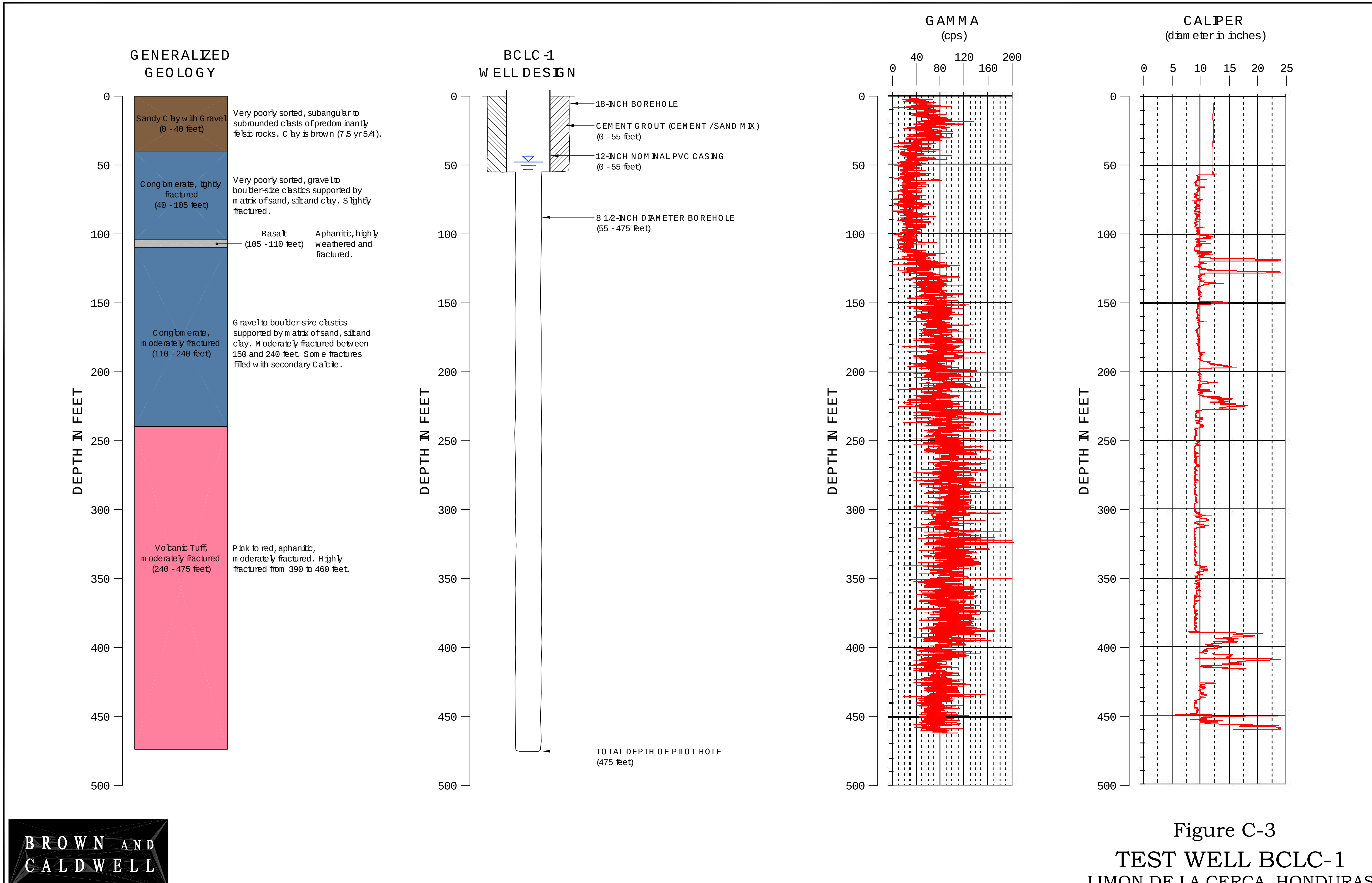

Figure C-3

TEST WELL BCLC-1

LIMON DE LA CERCA, HONDURAS

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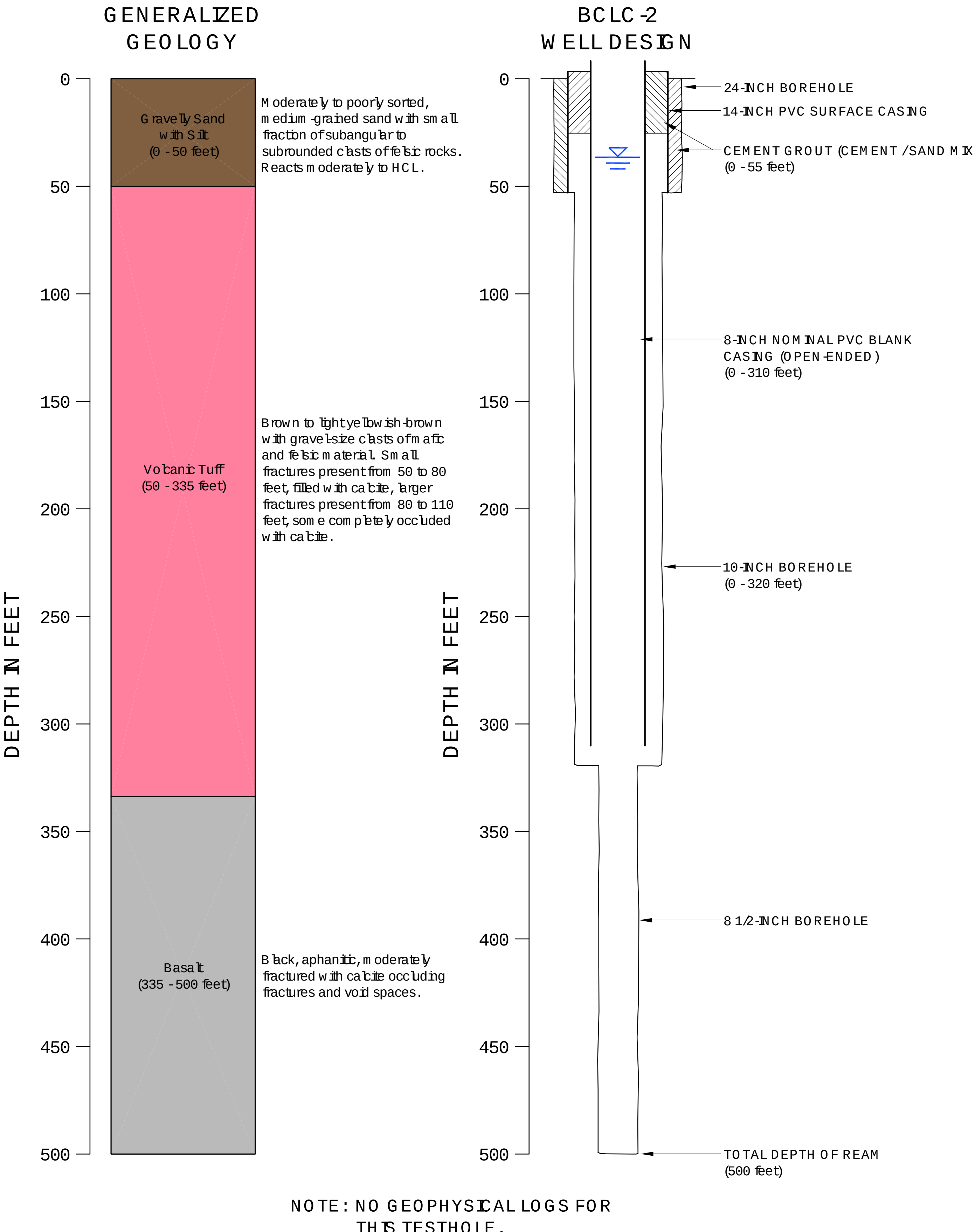

BROWN AND CALDWELL

Figure C-4

TEST WELL BCLC-2

LIMON DE LA CERCA, HONDURAS

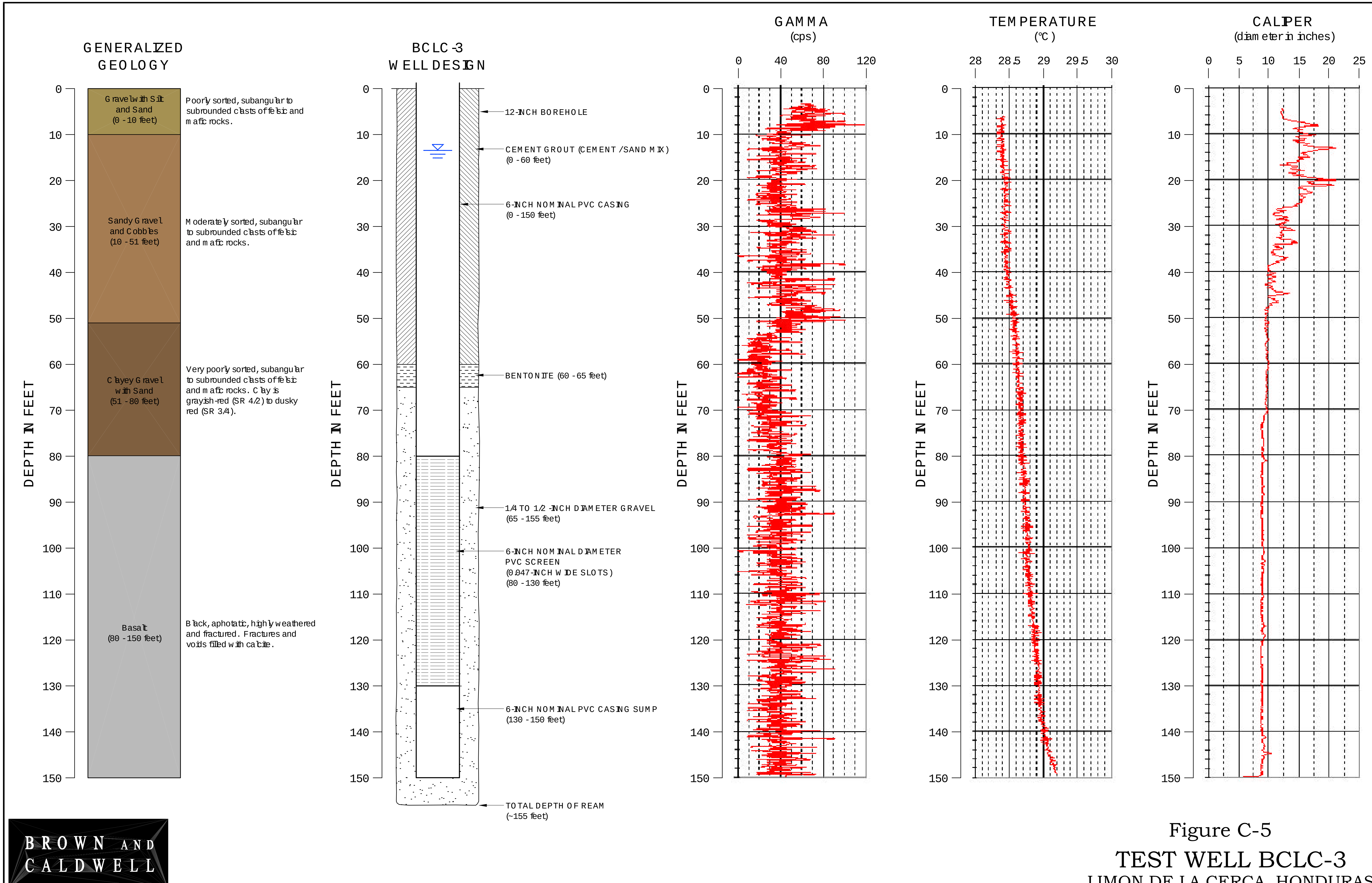

Figure C-5
TEST WELL BCLC-3
LIMON DE LA CERCA, HONDURAS

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In summary, drilling penetrated two principal units. An upper alluvial unit which is approximately 50 feet thick, and a lower bedrock unit. The alluvial unit is composed of varying mixtures of clay, sand and gravel. The bedrock unit is composed of a series of lahar and volcanic flows.

4.0 GEOPHYSICAL LOGGING AND VIDEO LOGGING

After completion of an exploratory borehole it was geophysically logged and a downhole video was conducted. The geophysical logging suite included spontaneous potential, point resistivity, gamma, temperature, and caliper. The geophyscial logs are presented in Figure C-3 through Figure C-5. The borehole was cleaned out by means of a siphon using air injection in preparation of video logging. Borehole cleaning was performed at 20-foot depth intervals. Once the fluid in the borehole was clear, the video log was run. Dates of these events are presented in Table C-3.

Table C-3. Summary of Geophysical and Video Logging

Well ID.	Date of Downhole Geophyscial log	Date of Downhole Video
BCLC-1	8/22/2001	8/18/2001
BCLC-2	not applicable	10/13/2001 & 11/1/2001
BCLC-3	8/29/2001	not applicable

The downhole video surveys conducted in boreholes BCLC-1 and BCLC-2 were performed using a Mark Products, Inc. Color GoeVision Jr. M1 video system. The video survey was conducted beginning at the base of the surface casing and continued to the total depth of the borehole. The articulating camera was controled from the surface and the survey team was able to stop and visually inspect any formation features along the way. A VHS recording was made of each video survey.

The downhole geophysical surveys were conducted using a combination of instruments from the Mount Sopris Instrument Company's MGX line of digital loggers (Figure C-6). An MGX digital logger was used for data capture and storage. A CTP-2492 combination caliper/temperature probe was alternated with a HLP-2357 combination standard gamma/spontaneous potential/single point resistivity probe. The probes were lowered down the wells using an electric winch and data was viewed in real time on a laptop screen and recorded by the datalogger. The equipment used for this down-hole survey is illustrated in the photograph below.

Figure C-6. Down-hole Geophysical Equipment

5.0 WELL DESIGN

Wells BCLC-1 and BCLC-2 were designed to seal the upper alluvial material from the underlying bedrock in order to determine the water potential of the bedrock aquifer. The seal consisted of blank casing installed from the surface through the alluvium. A minimum of 5 feet of bentonite was installed at the base of the casing and sand grout was used to fill the remainder of the annulus. Wells BCLC-1 and BCLC-2 do not have gravel pack but are open-hole wells.

After the original design, BCLC-1 was retrofitted with a 6-inch PVC casing and screen to 443 feet to protect the pump from loose gravel during aquifer testing. BCLC-2 was fitted with an 8-inch PVC casing to 310 feet to protect the pump during aquifer testing. The geophysical logs and video indicated the presence of several fractures that were suspected of having the potential to provide water. The diameter of each well was selected on estimated yield from evaluation of lithologic log, drill rig performance, and geophysical and video logs.

Well BCLC-3 was designed to evaluate the water potential of the alluvial material near the Choluteca River. The screen interval was selected based on visual observation of drill cuttings and on promising geophyscial readings on the interval from the 80 feet to 130 feet depth. The well is constructed of 6-inch diameter PVC which can accommodate a submersible pump of sufficient size for the expected yield of the well. The screen slot design was 0.047-inch slots.

6.0 WELL CONSTRUCTION

The construction of each well is shown in Figure C-3 through Figure C-5 of this Appendix. Completion of the wells were overseen by both Brown and Caldwell and ATICA staff. Details of well construction are shown in Table C-4. Wells were constructed after reaming the exploratory borehole to the necessary diameter. The surface completion of each well constisted of cement grout to the land surface with a protective concrete box constructed over the well head. A locked steel access port was fitted to the concrete box.

Wells BCLC-1 and BCLC-2 are open-borehole wells and do not have filter packing, although casing was installed in both wells to protect the pumps during aquifer pump tests, pictured in Figure C-7. Well BCLC-3 is constructed with gravel pack and PVC screen.

Figure C-7. Installation of PVC Casing

Table C-4. Summary of Well Construction

Well ID.	BCLC-1*	BCLC-2*	BCLC-3
Date started	10/31/2001	10/22/2001	9/6/2001
Date Completed	11/1/2001	10/23/2001	9/7/2001
Diameter of Borehole	18" to 55' 8.5" from 55-475'	18" to 60' 10" to 500'	12.25" to 155'
Total depth of Well (ft, bgs)	475	500	155
Casing/Screen Material	6-inch PVC	8-inch PVC	6-inch PVC
Total Casing Length	55' of 12" 210' of 6"	60' of 14" 310' of 8"	100'
Total Screen Length (ft)	233	None	50
Casing interval (ft, bgs)	0-210	0-310	0-80 130-150
Screen interval	210'-443'	None	80'-130'
Screen slot size	32 mm	None	32 mm
Sanitary Seal Material	sand grout	sand grout	sand grout
Sanitary Seal Interval (ft, bgs)	0-55	0-60	0-60
Gravel Pack material	none	none	3/8-inch gravel
Gravel Pack interval (ft, bgs)	none	none	65-155
Bentonite Seal Material	bentonite	bentonite	bentonite
Bentonite Seal interval (ft, bgs)	45-50	50-55	60-65

* Note – BCLC-1 and BCLC-2 are open-borehole wells and do not have filter pack.

7.0 WELL DEVELOPMENT

Each well was developed using a 4-inch galvanized pipe siphon. Air injected at the base of the siphon forced water to the surface. The siphon was moved through the full depth of each well at twenty foot intervals. Development at each interval continued until the water was predominantly clear and free of sand. Activities relating to well development are summarized in Table C-5.

Table C-5. Well Development Summary

Well ID.	BCLC-1	BCLC-2	BCLC-3
Date Started	8/10/2001	10/30/2001	9/8/2001
Date Ended	8/10/2001	10/31/2001	9/8/2001
Total hours development	6	15	16
Description of Method	siphon/air injection	siphon/air injection	siphon/air injection
Discharge rate/Discharge depths	not measured	27 gpm at 340' 12 gpm at 360' 11 gpm at 420' 14 gpm at 450'	65 gpm

8.0 AQUIFER TESTS

Short term and long term aquifer tests were performed on selected wells to evaluate the water resource development potential of both the fractured bedrock units and alluvium. These tests are outlined in more detail below.

8.1 Step Rate Discharge Tests

A step rate discharge test was conducted on each well to evaluate the specific capacity of the well and collect data to be used in groundwater modeling. Prior to constructing the step rate test, a small scale test was conducted to determine the maximum pumping rate for the well and to gather information to determine the pump rates to be used for each step. The sep rate discharge tests are summarized in Table C-6.

Table C-6. Summary of Step Rate Discharge Tests

Well ID.	BCLC-1	BCLC-2	BCLC-3
Date Started	11/5/2001	11/10/2001	9/18/2001
Duration (hours)	6	8	8
Size/type of pump	10-hp submersible	5-hp submersible	10-hp submersible
Depth of Pump (ft, bgs)	300	310	140
Static Water level (ft, bgs)	40.3	42.8	13.42
Specific Capacity	5 gpm, 0.22 gpm/ft 10 gpm, 0.14 gpm/ft 15 gpm, 0.09 gpm/ft	30 gpm, 3.9 gpm/ft 60 gpm, 2.4 gpm/ft 90 gpm, 2.2 gpm/ft	24 gpm, 1.03 gpm/ft 36 gpm, 0.99 gpm/ft 51 gpm, 0.82 gpm/ft 68 gpm, 0.73 gpm/ft

A 5.25-hour step-rate test was conducted at BCLC-1 on November 5, 2001. The static water level prior to commencement was approximately 49.4 feet bgs. The well was pumped at five step-rates of approximately 30, 60, 90, 120, and 130 gpm. Although the aquifer was pumped at 130 gpm for the first five minutes of the final step, it could only be pumped at 120 gpm for the remainder of the step. At a maximum rate of 120 gpm, the maximum drawdown at the end of the test was approximately 129.04 feet. After 10 minutes, the water level recovered to approximately 94 percent of the static level. During this test, the specific capacity ranged between 1.1 and 10.6 gallons per minute per foot of drawdown (gpm/ft). The Theis Recovery method was used to analyze the recovery data. The following formula was used:

$$T = 264(Q)/(?s)$$

where:

T = Transmissivity (gpd/ft)
Q = weighted average discharge rate (gpm)
?s = change in ratio t/t' over one log cycle
t = time since pumping started (min)
t' = time since pumping ended (min)

This method yielded a transmissivity value for BCLC-1 of approximately 287 gpd/ft. Figure C-8 shows the Theis Recovery plot for well BCLC-1.

A 3.5-hour step-rate test was conducted at BCLC-2 on November 10, 2001. The static water level was approximately 42.78 feet bgs. The well was pumped at three step-rates of approximately 5, 10, and 15 gpm. At a maximum rate of 15 gpm, the maximum drawdown at the end of the test was approximately 170.91 feet. After 6.5 hours, the water level recovered to approximately 84 percent. During this test, the specific capacity ranged between 0.2 and 0.1 gpm/ft of drawdown. The Theis Recovery method was used to analyze the recovery data. The formula for transmissivity described above was used for the BCLC-2 step test data.

This method yielded a transmissivity value of approximately 18 gpd/ft. Figure C-9 shows the Theis Recovery plot for well BCLC-2.

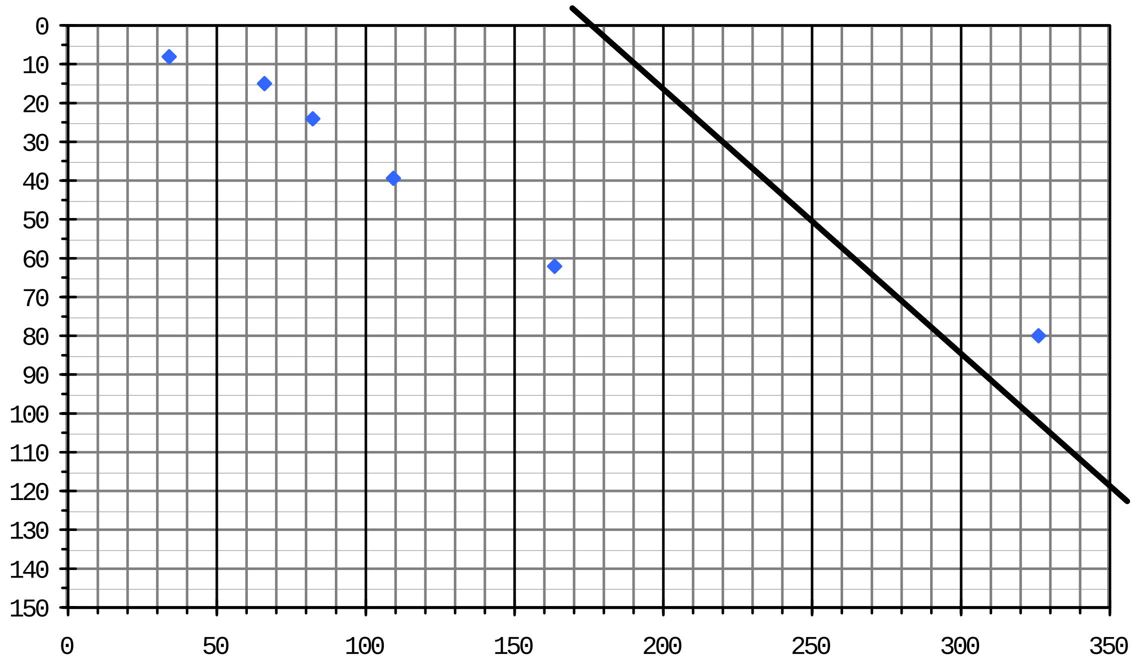
An 8-hour step-rate test was conducted at BCLC-3 on September 18, 2001. The static water level was approximately 13.42 feet bgs. The well was pumped at five step-rates of approximately 24, 36, 45, 51, and 68 gpm. At a maximum rate of 68 gpm, the maximum drawdown at the end of the test was approximately 96.63 feet. After 30 minutes, the water level recovered to 88 percent. Specific capacity measured during the step-rate test ranged between approximately 5.5 to 0.8 gpm/ft. The Theis Recovery method was used to analyze the recovery data. The formula for transmissivity described above was used for the BCLC-3 step test data.

This method yielded a transmissivity value for well BCLC-3 of approximately 160 gpd/ft. Figure C-10 shows the Theis Recovery plot for well BCLC-3.

8.2 Multiple Well Aquifer Test

The constant rate pumping test for well BCLC-1 was conducted from November 6 to November 9, 2001. A 10-horsepower submersible pump set at 300 feet bgs was used for the test. Based on the results of the step test the constant rate test flow rate was set at 90 gallons per minute. Flow was measured using a 55-gallon drum and a chronometer. Static water level prior to pumping was 50.02 feet bgs. BCLC-2 was used as a monitoring well and was monitored frequently throughout the test. Other wells in the vicinity of BCLC-1 that were monitored during the test included LC2 (Atlas), Iglesia de Cristo, and Luis.

A seventy-two-hour constant-rate test was conducted at BCLC-1 at 90 gpm. on November 6 - 9, 2001. Static water level was measured at approximately 50.02 feet bgs. BCLC-2 was utilized as a monitoring well during the pumping of BCLC-1. No response was observed in BCLC-2. Drawdown was approximately 95.56 feet at the end of the test in BCLC-1. After the pump test was complete, recovery water levels were recorded. After 3 hours, the water level recovered to approximately 90 percent. The Cooper-Jacob method was used to analyze the drawdown data; this method plots drawdown in feet versus time in minutes. The Theis Recovery method was then used to analyze recovery data; this method plots residual drawdown versus t/t' (t = time since pumping started in minutes, t' = time since pumping ended in minutes). The formula for transmissivity described above was used for both methods.



t = time since pumping started (min)
t' = time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q /Δs (gpd/ft)

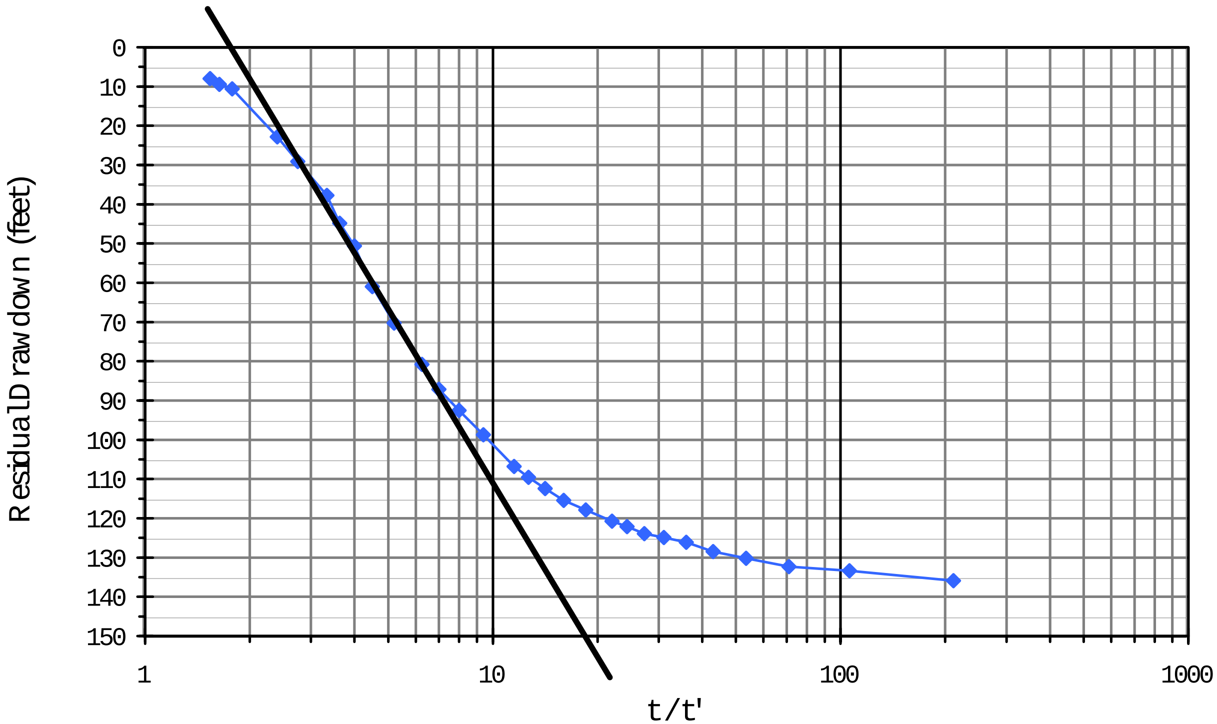
T = (264)(86)/(79)
T ~ 287 gpd/ft

BROWN AND CALDWELL
Phoenix, Arizona

USAID - HONDURAS
WELL BC LC-1

FIGURE C-8
THEIS RECOVERY PLOT

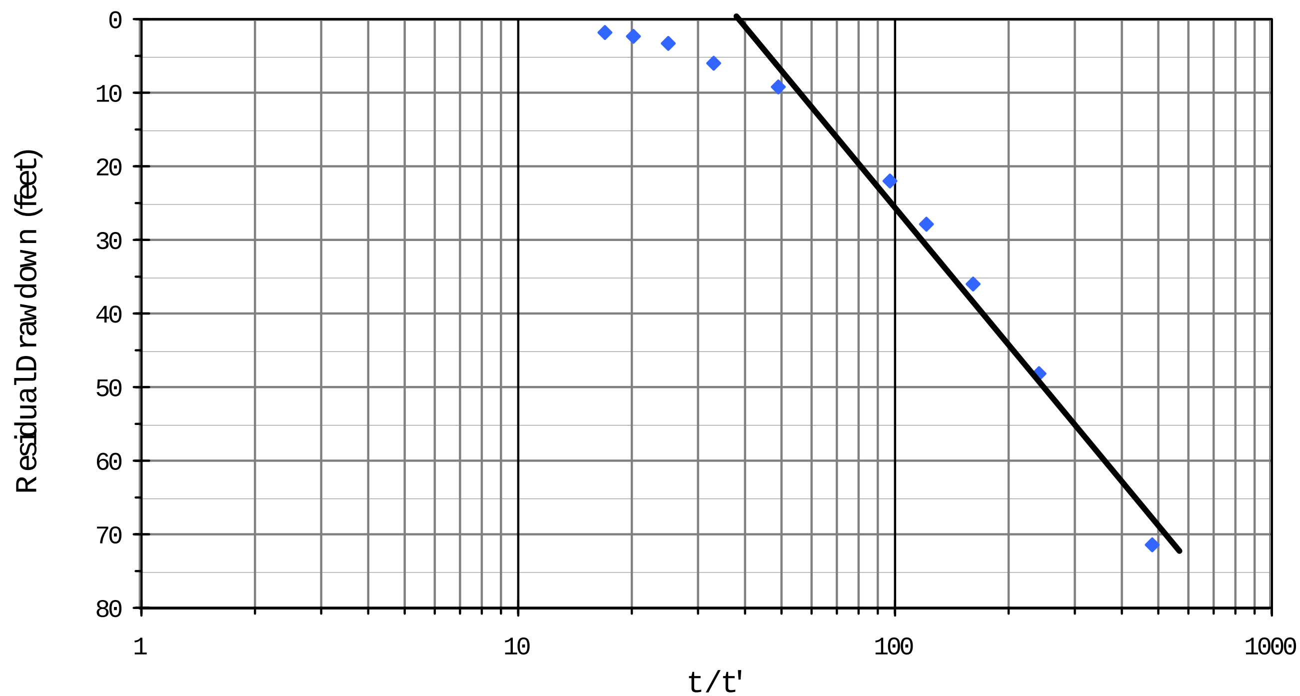
P:\Gen\GW_RES\Honduras\Choluteca\Pump Tests\Figure C-8-9,11-12.xls\App.C Fig.8



t= time since pumping started (min)
t'= time since pumping ended (min)
Δs= Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(9.3)/(140)
T ~ 18 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BC LC-2	FIGURE C-9 THEIS RECOVERY PLOT



t = time since pumping started (min)
t' = time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(37)/(61)
T ~ 160 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BC LC-3	FIGURE C-10 THEIS RECOVERY PLOT

P:\Gen\GW_RES\Honduras\Choluteca\Pump Tests\Figure 10.xls\Figure C-10

Analysis of the long-term aquifer test data from well BCLC-1 estimates transmissivity in the deep volcanic zone at the site to be between 1,600 and 4,750 gallons per day per foot (gpd/ft). Figure C-11 and Figure C-12 show the Cooper-Jacob and Theis Recovery plot, respectively, for well BCLC-1.

Due to the low yield observed during well development and during the step drawdown test in BCLC-2, a constant rate test was not performed in this well. Results of the step drawdown test conducted at BCLC-3 on September 18, 2001 indicated that a constant rate test was not required for that well.

9.0 WATER QUALITY SAMPLING

A sample of groundwater was collected from each new project well either at the end of well development or at the end of the step-rate discharge test. This sampling was conducted in support of the water quality component of the Honduras Groundwater Monitoring Study.

Each well was sampled for general chemistry constituents including acidity, alkalinity, hardness, bicarbonate, calcium, magnesium, manganese, phosphates, sulfates, nitrates and nitrites, sodium, and potassium. Each well was also sampled for selected heavy metals including; antimony, arsenic, lead, mercury, selenium, cadmium, chromium, nickel, silver and zinc. In addition, most wells were analyzed for total and fecal coliform to assess the amount of fecal matter infiltrating into the groundwater supply. Other chemical constituents were selected for analysis on a case by case basis including volatile organic chemicals (VOCs), pesticides, and herbicides. The location of the well provided the main criteria for establishing what analytes would be analyzed. For example, a well that is located in close proximity to an agricultural setting would be analyzed for pesticides and herbicides to assess if the chemicals used to fertilize and repel insects and rodents from the crops were infiltrating to the groundwater supply. Similarly, for wells that are located in the vicinity of a factory, VOCs would be analyzed to determine the presence or absence of organic chemicals used for manufacturing or industrial cleaning that are being released to the groundwater supply. The groundwater sampling procedure for all wells included field water quality measurements (pH, temperature, and conductivity) to confirm that pumped groundwater was representative of aquifer pore water. Samples were collected in containers supplied by Jordan Laboratories of San Pedro Sula. Samples were immediately labeled and placed on ice in laboratory-supplied coolers. Samples for physical parameters and bacteriological analysis were shipped overnight to Jordan Laboratories in San Pedro Sula. Samples for metals analysis were shipped to Southern Petroleum Laboratories in Houston, Texas. Proper chain of custody documentation was filled out and accompanied samples from collection to laboratory analysis.

The water quality sample for laboratory analysis for BCLC-1 was collected on November 5, 2001 during the step drawdown test. The water quality sample for BCLC-2 was collected on October 31, 2001 during well development when the siphon was located at 420 feet bgs. The water quality sample for BCLC-3 was collected on September 18, 2001 during a step drawdown test.

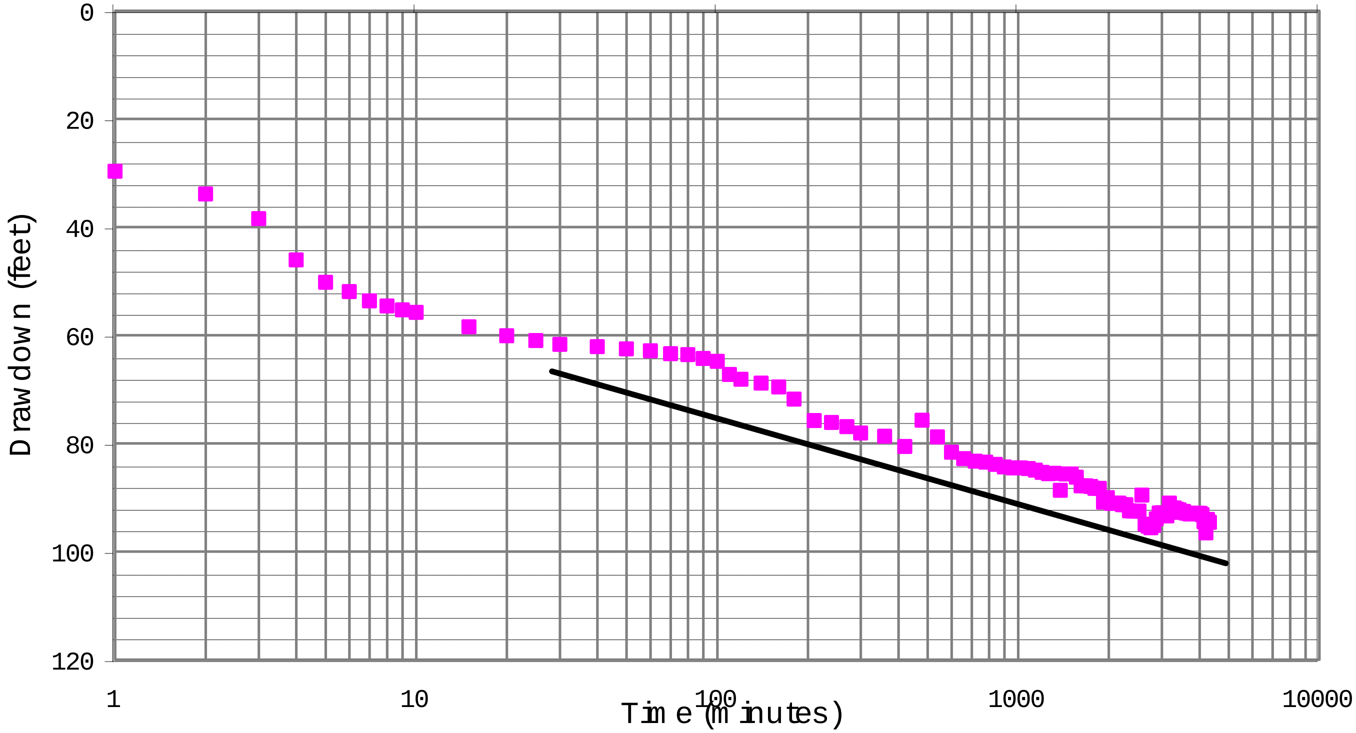
Water quality samples for laboratory analysis were also collected from specific pre-existing wells that comprise the groundwater monitoring network for Limón de la Cerca. Water quality samples were collected from wells LC3, LC1, LC2 (Atlas), and Luis between October 29 and 31, 2001. These analytical results are presented in Table G7, as well as laboratoy reports, at the end of this Appendix.

BCLC-1. The groundwater sample from BCLC-1 was submitted for selected general chemistry constituents and metals. The only metal detected was zinc (0.175 milligrams per liter (mg/L)), below the guideline established by WHO. The WHO guideline for zinc is 3 mg/L (WHO, 1996). Other constituents reported at BCLC-1 include conductivity (483 μS/cm) (equivalent to 290 mg/L total dissolved solids) and total coliform (16 UFC/100 mL). The current WHO guidelines do not address conductivity or coliform concentrations. However, the presence of coliform indicates that infiltration of fecal matter in this area may be an issue that needs to be addressed in future treatment planning.

BCLC-2. Newly installed well BCLC-2 was sampled for general chemistry constituents as well as metals. Each of the constituents subject to analysis were reported below the minimum detection limit capabilities of the laboratory. The exception to this was elevated concentrations of arsenic and total coliform. The reported concentration of arsenic was 0.0079 mg/L. This concentration falls below the WHO guideline for arsenic in drinking water (0.01 mg/L) (WHO, 1996). Reported concentrations for total coliform are recorded at 34 UFC/100 mL. WHO does not provide a guideline for coliform concentrations but the presence of coliform indicates that infiltration of fecal matter in this area may be an issue that needs to be addressed in future treatment planning.

BCLC-3. Newly installed well BCLC-3 was analyzed for general chemistry constituents, fecal and total coliform, selected heavy metals, pesticides, herbicides, and VOCs. Each of the constituents subject to analysis were reported below the minimum detection limit capabilities of the laboratory. The only exception was a slightly elevated concentration of zinc (0.0855 mg/L). While this concentration exceeds the laboratory's minimum detection capabilities, it falls below the recommended WHO guideline of 3 mg/L (WHO, 1996).

Water Wells. The remaining samples collected from existing municipal wells were analyzed for general chemistry constituents and selected heavy metals. In addition, each sample was analyzed for the presence of coliform matter. Each of the constituents subject to analysis for each of these wells were reported below the minimum detection limit capabilities of the laboratory with the consistent exception of zinc. This metal is reported at LC-1—Ricardo Soriano, LC-2—Atlas, and LC-3—Bolsa Samaritan. The concentrations are reported at 0.0302 mg/L, 0.0411 mg/L and 0.0537 mg/L, respectively. Again, each of these reported elevated concentrations fall below the WHO recommended guideline of 3 mg/L zinc (WHO,1996). Concentrations of zinc in groundwater of Limón de la Cerca may be representative of an area characterized by volcanic terrain, such as the rugged uplands surrounding the valley.

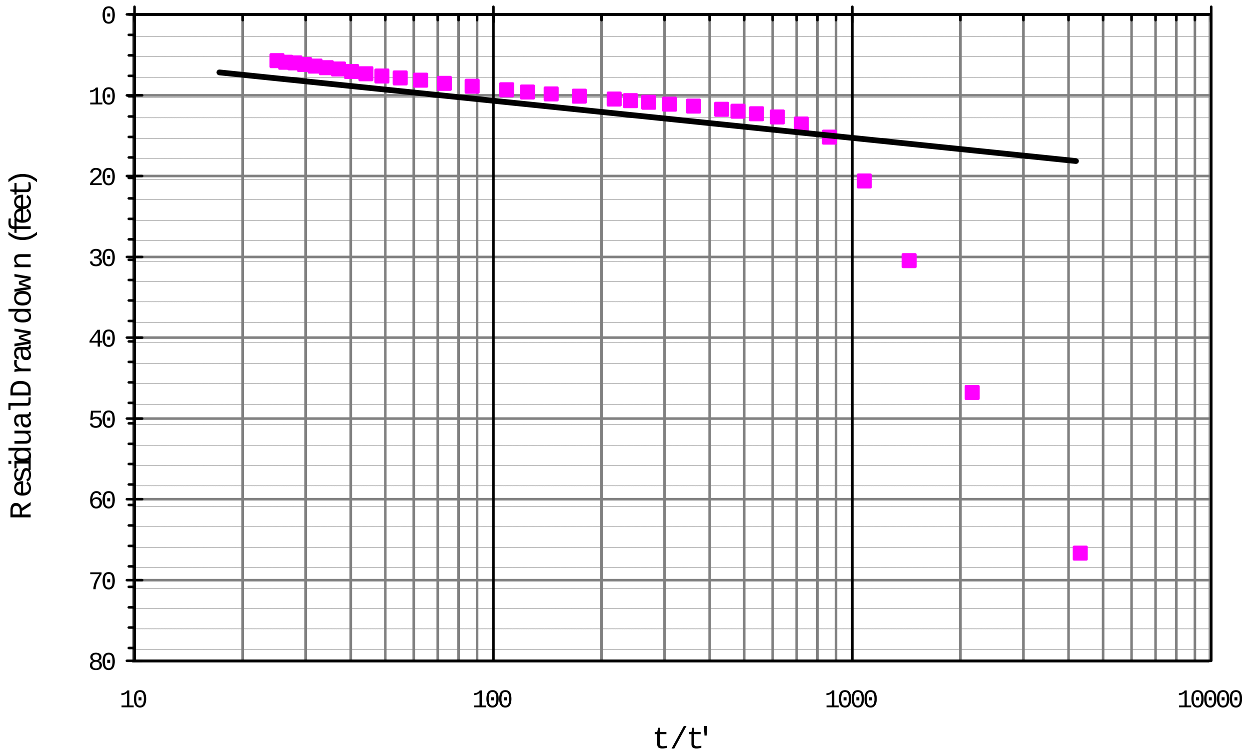


Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(90)/(15)
T ~ 1,600 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID-HONDURAS WELL BC LC-1	FIGURE C-11 COOPER-JACOB PLOT

P:\Gen\GW_RES\Honduras\La Lima\Pump Tests\Figure C-8-9,11-12.xls\App.C Fig.11



t = time since pumping started (min)
t' = time since pumping ended (min)
Δs = Change in drawdown over one log cycle (feet)
Q = Time weighted average discharge rate (gpm)
T = Transmissivity = 264Q/Δs (gpd/ft)

T = (264)(90)/(5)
T ~ 4,750 gpd/ft

BROWN AND CALDWELL Phoenix, Arizona	USAID - HONDURAS WELL BC LC-1	FIGURE C-12 THEIS RECOVERY PLOT

P:\Gen\GW_RES\Honduras\Choluteca\Pump Tests\Figure C-8-9,11-12.xls\App.C Fig.12

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Brown & Caldwell

Certificate of Analysis Number:

01110476

Report To:	Brown & Caldwell Barbara Goodrich 201 North Civic Drive Suite 200 Walnut Creek CA 94596-3864 ph: (925) 210-9010 fax: (925) 937-9026		Project Name:	USAID Groundwater Resources 21365.
			Site:	Choluteca, Honduras
			Site Address:	
			PO Number:	
			State:	Client Specified
			State Cert. No.:	
Fax To:		fax:	Date Reported:	

Client Sample ID	Lab Sample ID	Matrix	Date Collected	Date Received	COC ID	HOLD
LC3 102001	01110476-01	Water	10/29/01 3:50:00 PM	11/12/01 10:00:00 AM	098067	☐
LC1 102001	01110476-02	Water	10/29/01 4:30:00 PM	11/12/01 10:00:00 AM	098067	☐
LU1S 102001	01110476-03	Water	10/29/01 5:15:00 PM	11/12/01 10:00:00 AM	098067	☐
LC2 Atlas 102001	01110476-04	Water	10/31/01 9:30:00 AM	11/12/01 10:00:00 AM	098067	☐
BCLC2 102001	01110476-05	Water	10/31/01 12:15:00 PM	11/12/01 10:00:00 AM	098067	☐
BCLC1 102001	01110476-06	Water	11/5/01 12:40:00 PM	11/12/01 10:00:00 AM	098067	☐
BC-V1-4	01110476-07	Water	11/8/01 10:30:00 AM	11/12/01 10:00:00 AM	098067	☐

11/28/01

Sonia West — Date
Senior Project Manager

Joel Grice
Laboratory Director

Ted Yen
Quality Assurance Officer

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID LC3 102001 Collected: 10/29/01 3:50:00 SPL Sample ID: 01110476-01

Site: Choluteca, Honduras

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			MCL	SW 7470A		Units: mg/L		
Mercury	ND	0.0002		1		11/20/01 14:10	R_T	926158
METALS BY METHOD 6010B, DISSOLVED			MCL	SW 6010B		Units: mg/L		
Antimony	ND	0.005		1		11/28/01 2:56	NS	926869
Arsenic	ND	0.005		1		11/26/01 21:18	NS	926014
Lead	ND	0.005		1		11/26/01 21:18	NS	926014
Selenium	ND	0.005		1		11/26/01 21:18	NS	926014
Cadmium	ND	0.005		1		11/25/01 18:57	EG	925360
Chromium	ND	0.01		1		11/25/01 18:57	EG	925360
Nickel	ND	0.02		1		11/25/01 18:57	EG	925360
Silver	ND	0.01		1		11/25/01 18:57	EG	925360
Zinc	0.0537	0.02		1		11/25/01 18:57	EG	925360

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

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8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID LC1102001 | Collected: 10/29/01 4:30:00 | SPL Sample ID: 01110476-02

Site: Choluteca, Honduras

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			MCL	SW7470A		Units: mg/L		
Mercury	ND	0.0002		1		11/20/01 14:10	R_T	926161
METALS BY METHOD 6010B, DISSOLVED			MCL	SW6010B		Units: mg/L		
Antimony	ND	0.005		1		11/28/01 3:21	NS	926873
Arsenic	ND	0.005		1		11/26/01 20:53	NS	926010
Lead	ND	0.005		1		11/26/01 20:53	NS	926010
Selenium	ND	0.005		1		11/26/01 20:53	NS	926010
Cadmium	ND	0.005		1		11/25/01 19:21	EG	925364
Chromium	ND	0.01		1		11/25/01 19:21	EG	925364
Nickel	ND	0.02		1		11/25/01 19:21	EG	925364
Silver	ND	0.01		1		11/25/01 19:21	EG	925364
Zinc	0.0302	0.02		1		11/25/01 19:21	EG	925364

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID LU1S 102001 | Collected: 10/29/01 5:15:00 | SPL Sample ID: 01110476-03

Site: Choluteca, Honduras

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			MCL	SW 7470A		Units: mg/L		
Mercury	ND	0.0002		1		11/20/01 14:10	R_T	926162
METALS BY METHOD 6010B, DISSOLVED			MCL	SW 6010B		Units: mg/L		
Antimony	ND	0.005		1		11/28/01 3:27	NS	926874
Arsenic	ND	0.005		1		11/26/01 21:24	NS	926015
Lead	ND	0.005		1		11/26/01 21:24	NS	926015
Selenium	ND	0.005		1		11/26/01 21:24	NS	926015
Cadmium	ND	0.005		1		11/25/01 19:27	EG	925365
Chromium	ND	0.01		1		11/25/01 19:27	EG	925365
Nickel	ND	0.02		1		11/25/01 19:27	EG	925365
Silver	ND	0.01		1		11/25/01 19:27	EG	925365
Zinc	ND	0.02		1		11/25/01 19:27	EG	925365

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit (MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID LC2 Atlas 102001 | Collected: 10/31/01 9:30:00 | SPL Sample ID: 01110476-04

Site: Choluteca, Honduras

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			MCL	SW 7470A		Units: mg/L		
Mercury	ND	0.0002		1		11/20/01 14:10	R_T	926163
METALS BY METHOD 6010B, DISSOLVED			MCL	SW 6010B		Units: mg/L		
Antimony	ND	0.005		1		11/28/01 3:33	NS	926875
Arsenic	ND	0.005		1		11/26/01 21:30	NS	926016
Lead	ND	0.005		1		11/26/01 21:30	NS	926016
Selenium	ND	0.005		1		11/26/01 21:30	NS	926016
Cadmium	ND	0.005		1		11/25/01 19:33	EG	925366
Chromium	ND	0.01		1		11/25/01 19:33	EG	925366
Nickel	ND	0.02		1		11/25/01 19:33	EG	925366
Silver	ND	0.01		1		11/25/01 19:33	EG	925366
Zinc	0.0411	0.02		1		11/25/01 19:33	EG	925366

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BCLC2 102001 Collected: 10/31/01 12:15:0 SPL Sample ID: 01110476-05

Site: Choluteca, Honduras

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			MCL	SW 7470A		Units: mg/L		
Mercury	ND	0.0002		1		11/20/01 14:10	R_T	926164
METALS BY METHOD 6010B, DISSOLVED			MCL	SW 6010B		Units: mg/L		
Antimony	ND	0.005		1		11/28/01 3:39	NS	926876
Arsenic	0.0079	0.005		1		11/26/01 21:37	NS	926017
Lead	ND	0.005		1		11/26/01 21:37	NS	926017
Selenium	ND	0.005		1		11/26/01 21:37	NS	926017
Cadmium	ND	0.005		1		11/25/01 19:39	EG	925367
Chromium	ND	0.01		1		11/25/01 19:39	EG	925367
Nickel	ND	0.02		1		11/25/01 19:39	EG	925367
Silver	ND	0.01		1		11/25/01 19:39	EG	925367
Zinc	ND	0.02		1		11/25/01 19:39	EG	925367

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

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8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BCLC1102001 | Collected: 11/5/01 12:40:00 | SPL Sample ID: 01110476-06

Site: Choluteca, Honduras

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			MCL	SW7470A		Units: mg/L		
Mercury	ND	0.0002		1		11/20/01 14:10	R_T	926165
METALS BY METHOD 6010B, DISSOLVED			MCL	SW6010B		Units: mg/L		
Antimony	ND	0.005		1		11/28/01 4:01	NS	926879
Arsenic	ND	0.005		1		11/26/01 21:59	NS	926025
Lead	ND	0.005		1		11/26/01 21:59	NS	926025
Selenium	ND	0.005		1		11/26/01 21:59	NS	926025
Cadmium	ND	0.005		1		11/25/01 19:56	EG	925370
Chromium	ND	0.01		1		11/25/01 19:56	EG	925370
Nickel	ND	0.02		1		11/25/01 19:56	EG	925370
Silver	ND	0.01		1		11/25/01 19:56	EG	925370
Zinc	0.175	0.02		1		11/25/01 19:56	EG	925370

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Client Sample ID BC-V1-4 | Collected: 11/8/01 10:30:00 | SPL Sample ID: 01110476-07

Site: Choluteca, Honduras

Analyses/Method	Result	Rep.Limit		Dil. Factor	QUAL	Date Analyzed	Analyst	Seq. #
MERCURY, DISSOLVED			MCL	SW 7470A		Units: mg/L		
Mercury	ND	0.0002		1		11/20/01 14:10	R_T	926168
METALS BY METHOD 6010B, DISSOLVED			MCL	SW 6010B		Units: mg/L		
Antimony	ND	0.005		1		11/28/01 4:08	NS	926880
Arsenic	ND	0.005		1		11/26/01 22:05	NS	926029
Lead	ND	0.005		1		11/26/01 22:05	NS	926029
Selenium	ND	0.005		1		11/26/01 22:05	NS	926029
Cadmium	ND	0.005		1		11/25/01 20:02	EG	925371
Chromium	ND	0.01		1		11/25/01 20:02	EG	925371
Nickel	ND	0.02		1		11/25/01 20:02	EG	925371
Silver	ND	0.01		1		11/25/01 20:02	EG	925371
Zinc	ND	0.02		1		11/25/01 20:02	EG	925371

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

APPENDIX D

Groundwater Flow Model

GROUNDWATER FLOW MODEL

Limón de la Cerca, Honduras

June 2002

1.0 INTRODUCTION

A numerical groundwater flow model was constructed for Limón de la Cerca as an interpretative tool to evaluate potential groundwater resources for the community. The process produced a preliminary groundwater flow model consistent with our understanding of hydrogeologic conditions in the area. The original intent of the model was for use in the evaluation of potential groundwater resources. The information collected to date, the conceptual geologic/hydrogeologic model of Limón de la Cerca, and this groundwater water flow model should serve as the basis for an initial understanding of the site and used accordingly. As additional geologic and hydrogeologic data are collected, the site conceptual model and groundwater flow model can be optimized, thereby increasing the groundwater flow model's effectiveness to be used as a tool to manage the community's groundwater resources.

1.1 Objectives

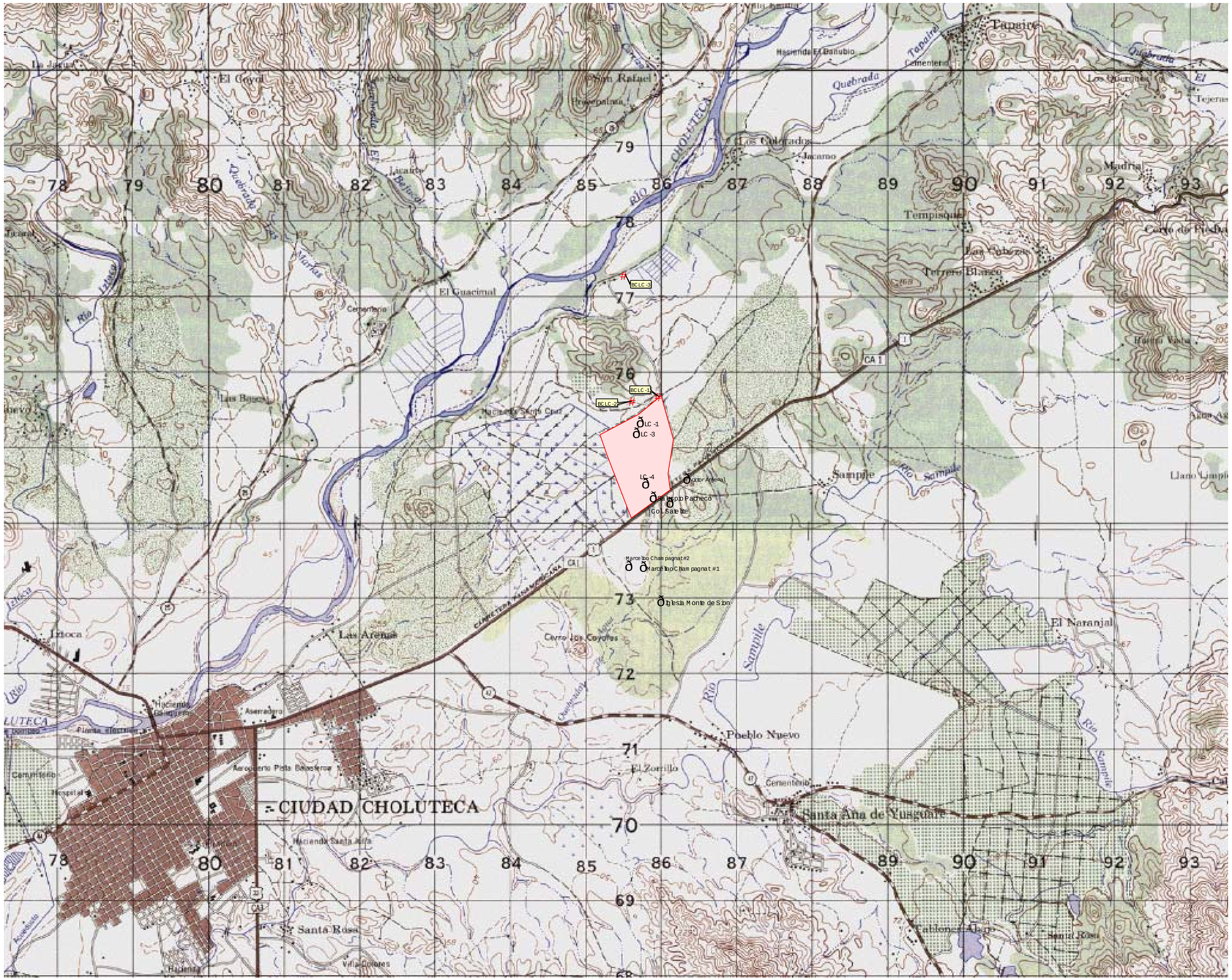
The following sections outline the purpose and objectives of the numeric groundwater flow model.

1.1.1 Purpose and Goals. The primary purpose and goal of this project was to develop a groundwater flow model to function as a potential interpretative tool to evaluate possible groundwater resources for the community of Limón de la Cerca.

1.1.2 Applicability. The original intent of the model was for use in the evaluation of potential groundwater resources available to support the relocation of population and subsequent growth at Limón de la Cerca. The results of the field investigation revealed complex geologic and hydrogeologic conditions in the area. Without further investigation, the use of the conceptual hydrogeologic model developed for the site and this groundwater model should be limited to supporting a general understanding of potential groundwater resources for the community. The information collected to date, the current conceptual geologic/hydrogeologic model, and the groundwater water flow model should serve as the basis for an initial understanding of the site and used accordingly. As additional geologic and hydrogeologic information is collected, the site conceptual model and understanding of groundwater flow can be refined thereby increasing the effectiveness of the groundwater flow model if used as a tool to manage the community's groundwater resources.

2.0 CONCEPTUAL MODEL

Limón de la Cerca lies within the wide valley floodplain of the Choluteca River. The Choluteca River is located to the north and west of Limón de la Cerca. The valley is bound to the north and southwest by rugged upland areas comprised of a variety of igneous rocks, including volcanic materials. The valley terrain is relatively flat, interrupted only by occasional low outlier hills of volcanic or other bedrock material. The Simpile River lies to the east and south of Limón de la Cerca. Several smaller tributaries are also found with the valley. Figure D-1 presents a topographic map of the Choluteca River valley.



N

1000 0 1000 2000 Meters

Legend

ð Existing Production Wells
\# BC Test Well Locations
Limon de la Cerca

FIGURE D-1

SITE MAP
LIMON DE LA CERCA

LIMON DE LA CERCA, HONDURAS

Based on information from existing drill records, and results of the field investigation, the hydrostratigraphic setting beneath the Choluteca River valley appears to be complex. The valley is surrounded by rugged uplands of igneous rocks. The valley consists of mudflow, alluvial, fluvial, igneous, and volcanic deposits. Numerous wells have been installed at different depths for domestic water production. During the field investigation, three wells were installed (BCLC-1, BCLC-2, and BCLC-3) in an effort to evaluate the hydrogeology and water quality at the site.

2.1 Aquifer System

For the conceptual model (described in Appendix A), the site is divided into three units. This is based on site stratigraphy, results from the geophysical survey, and the observed aquifer response to various pump/step draw-down tests performed at the site.

The hydrostratigraphic units are depicted in the generalized cross-section presented in Figure D-2 and are described briefly, as follows:

2.1.1 Upper Alluvial Aquifer. Represents the uppermost water-bearing unit at the site. This zone is comprised of unconsolidated mudflow, alluvial, and fluvial deposits of interbedded and discontinuous beds of clays, silts, sands, and gravels. Total thickness of the alluvial deposits is approximately 10 – 30 meters, and is underlain by igneous rocks.

2.1.2 Upper Bedrock Aquifer. Represents a highly fractured volcanic tuff and conglomerate zone of relatively high hydraulic conductivity. Based on the results of the field investigation, this aquifer is estimated to be approximately 15-50 meters thick.

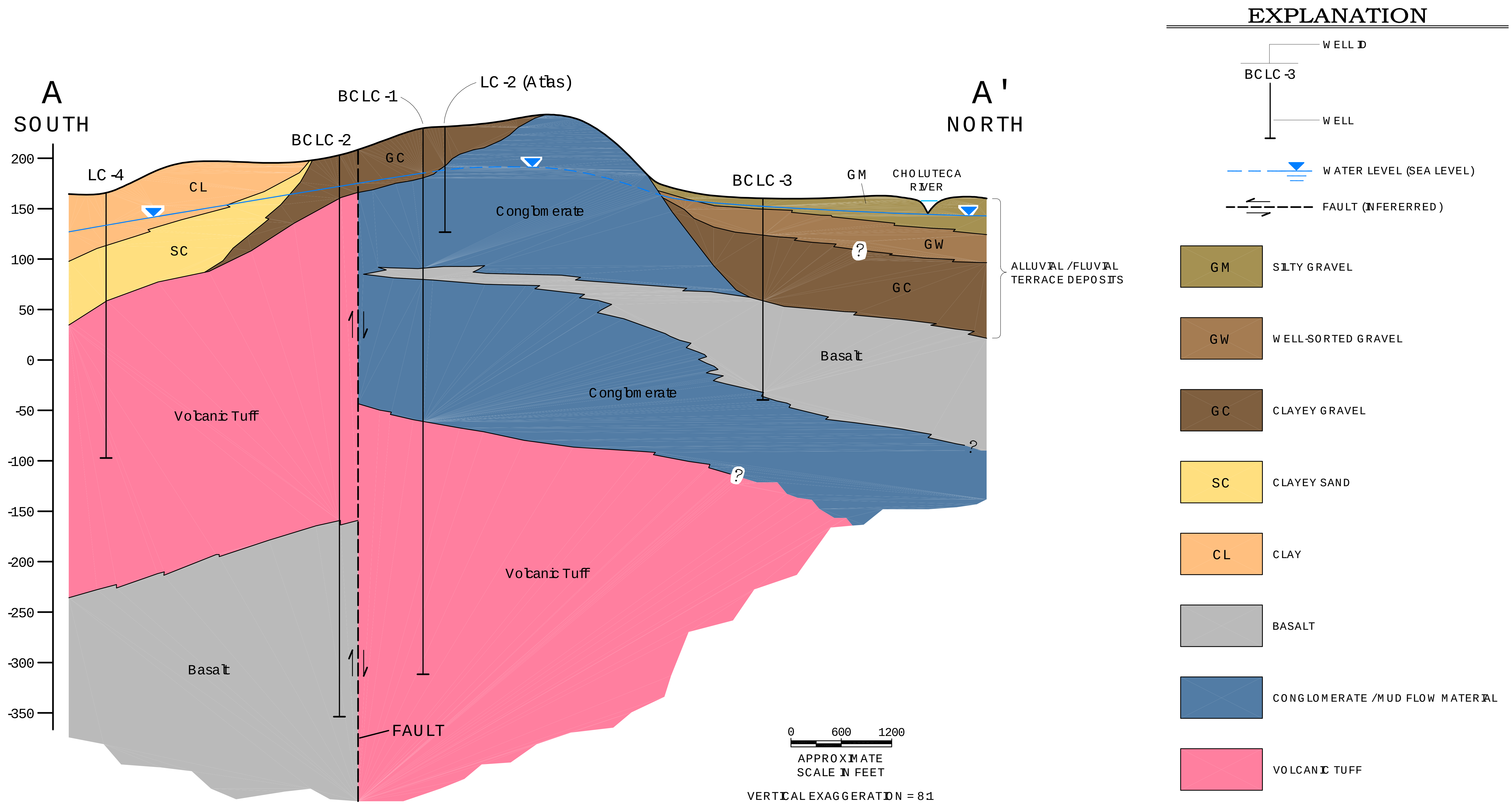
2.1.3 Lower Bedrock Aquifer. Represents a fractured basalt and volcanic tuff bedrock zone. It has a considerably lower hydraulic conductivity than the Upper Bedrock Aquifer. Based on the results of the field investigation, this aquifer is estimated to be approximately 60-80 meters thick.

2.2 Hydrogeologic Boundaries

The numeric groundwater flow model is bounded to the northwest by the Choluteca River. The Simpile River and several smaller rivers also traverse the valley. Information on the flow rates of these two major rivers was not available. To the south, east, and northwest, upland areas comprised of a variety of igneous rocks surround the valley. For the numeric groundwater flow model, these areas are designated as no-flow boundaries.

2.3 Hydraulic Properties

Short-term and long-term aquifer tests were performed on selected wells to evaluate the water resource development potential. A step draw-down test was performed on bedrock test well BCLC-1. Because it was the highest yielding well of the two newly installed bedrock wells, BCLC-1 was selected for the long-term, 72-hour aquifer pumping test. During the test, the well maintained a flow rate of 90 gpm with a maximum draw-down of 29.43 meters.



BROWN AND CALDWELL

Figure D-2
CROSS-SECTION
LIMON DE LA CERCA, HONDURAS

P:\Cad\ES\HONDURAS\Limon Cerca\LC-1.dwg (1=1) 01-17-02 JCollier

Due to marginal yields, very limited tests were conducted in wells BCLC-2 and BCLC-3. Results for the step draw-down test performed on bedrock well BCLC-2 indicated that yields from this well would likely be less than 35 gpm. Similarly, the aquifer step draw-down test conducted on alluvial well BCLC-3 indicated that well yields would likely be less than 20 gpm.

Records indicate that an aquifer test was performed on LC-4 by SERPE after its construction. During the 24-hour aquifer test, the well maintained a flow rate of 117 gpm with a maximum draw-down of 7.87 meters. Currently, well LC-4 is used for domestic water purposes and pumps intermittently at approximately 200 gpm (0.76 m^3/minute) (SANAA, 1977). Table D-1 summarizes the transmissivities determined during step-tests and aquifer tests of wells BCLC-1, BCLC-2, BCLC-3, and LC-4.

Table D-1. Aquifer Transmissivity and Hydraulic Conductivity

WELL ID	Transmissivity, m^2/day	Hydraulic conductivity, m/day
LC-4	770 – 1920	15 – 30
BCLC-1	0.4 - 61	0.003 – 0.5
BCLC-2	0.23	0.002
BCLC-3	9.83	0.1-0.4

2.4 Sources and Sinks

Based on previous studies, interviews with local representatives, and the field investigation, the conceptual model was developed based on the understanding that the fractured igneous rocks of the upland areas serve as the major source of groundwater recharge to the alluvium and bedrock. The Choluteca River is considered to be the primary discharge area, and the Simpile River serving as a secondary discharge area. Precipitation recharge to the northern and southern highlands flows through bedrock and sediments, towards the valley, and ultimately discharges to the rivers. The Choluteca valley receives between approximately 1 and 1.8 m of precipitation annually, with most of the precipitation occurring from May through October, during the monsoon season (SANAA, 1977).

2.5 Conceptual Water Budget

A conceptual water budget for the aquifer system in Limón de la Cerca was calculated to provide constraints for mathematical modeling. The conceptual budget was developed based on previous investigations, field data collection, and anecdotal information from long-term residents.

For the modeled area, inflow to the aquifer system consists mainly of recharge from precipitation. Groundwater is removed from the system via (1) municipal and private well pumping, and (2) discharge to the Choluteca River and Sampile Rivers.

2.5.1 Inflow. The Choluteca valley receives between 1 and 1.8 meters of precipitation annually with most of the precipitation occurring from May through October. For the model, this averages about 3.8x10-3 m/day, approximately 1 percent of which infiltrates into the aquifer. The primary source of recharge is from the surrounding upland areas. Approximately 45,000,000 m2 of land area was estimated to represent the total recharge area associated with the model domain. Assuming a 1 percent infiltration rate, an estimated 1,550 m3/day of water is recharging to the aquifer system from the upland areas. The geographic boundaries for the model are illustrated in Figure D-3.

The secondary recharge area is associated with percolation of precipitation through the alluvium. Approximately 92,000,000 m^2 was estimated to be the total area represented by the valley alluvial materials. Assuming a 0.5 percent infiltration rate, an estimated 3,500 m^3/day is recharging to the aquifer system from percolation through the alluvium. .

2.5.2 Outflow. Five Limón de la Cerca wells pump groundwater for use by residents. In addition to these wells, a number of other wells were identified that supply water to surrounding communities and private homes (Table 3-2). Because an official estimate of total pumping from these wells is not available, it was assumed that the accumulative total pumping from all wells is approximately 1,080 m^3/day.

Discharge of groundwater to the Choluteca River was calculated based on a 10,000 meter river segment length, 35 meter average channel width (half the total with), an estimated hydraulic conductivity of 0.6 meter per day, and a gradient of 0.01. Discharge to the Choluteca River using this method is estimated to be approximately 2,100 m^3/day.

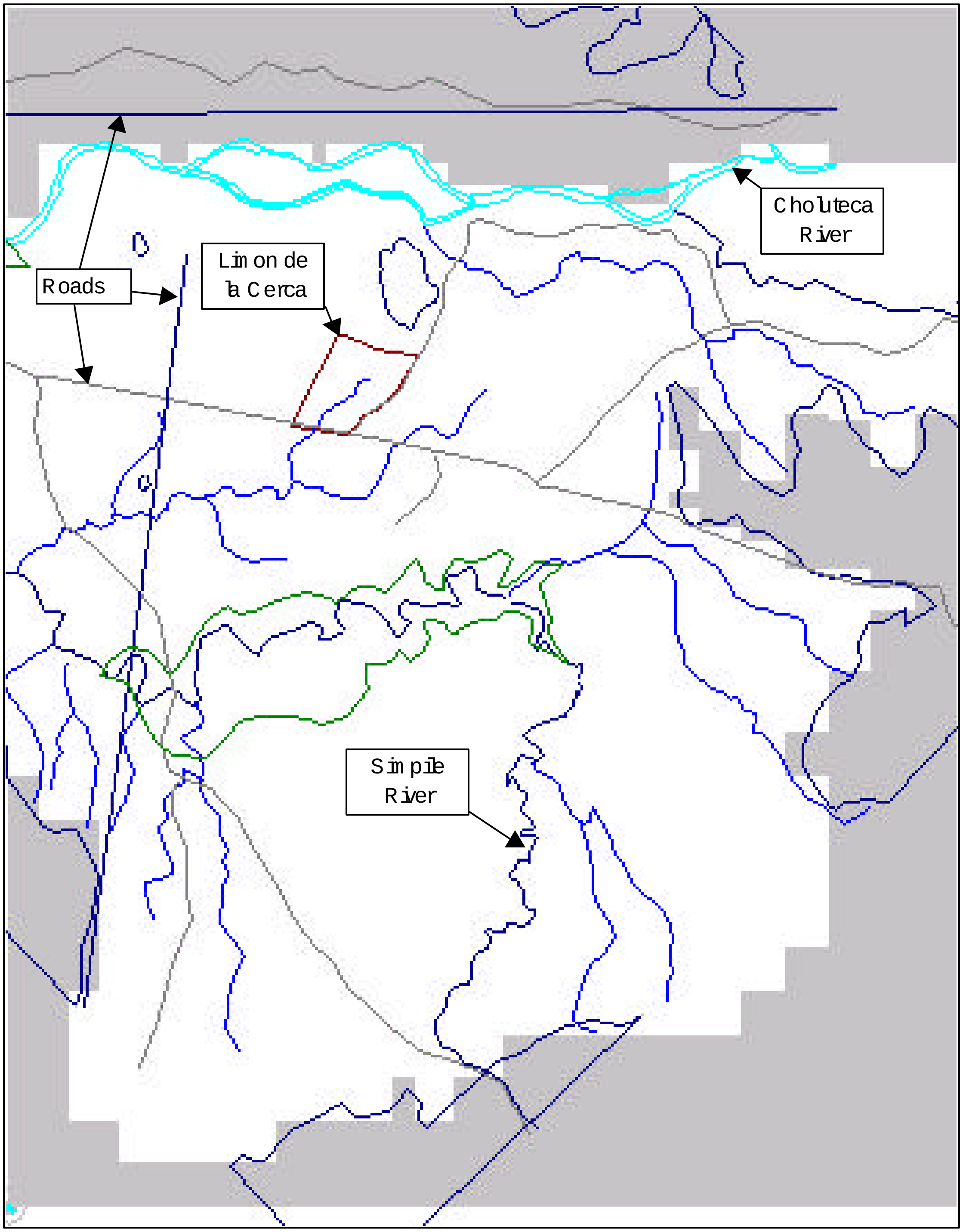
Discharge of groundwater to the Sampile River was calculated based on a 7,500 meter river segment length, 20 meter average channel width, an estimated hydraulic conductivity of 0.6 meter per day, and a gradient of 0.01. Discharge to the Sampile River using this method is estimated to be approximately 900 m^3/day.

Table D-2 below summarizes the annual, conceptual groundwater budget for the Limón de la Cerca model region.

Table D-2. Conceptual Groundwater Budget

IN	M^3 per day
Recharge Up-lands	1,550
Recharge Valley Alluvium	3,500
Total	5,050
OUT	
Limón de la Cerca pumping	580
Other well pumpings	500
Discharge to rivers	3,000
Total	4,080
IN – OUT (change in storage)	970

Based on these estimates, there is a daily surplus of 970 m^3, indicating that groundwater supplies are being added to the aquifer storage.



North

No-Flow Boundary

Secondary Rivers

FIGURE D-3

MODEL DOMAIN

Limón de la Cerca, Honduras
USAID

BROWN AND CALDWELL

*Not to Scale

3.0 COMPUTER CODE

The modular, three-dimensional, finite difference groundwater model code, typically referred to as MODFLOW, was used for this project. The U.S. Geological Survey (McDonald and Harbaugh, 1988) developed the original code; however, a slightly modified version of the code marketed by Environmental Simulations Inc. was used for this site. The version is designed to interact with Groundwater Vistas, a pre- and post-processor used for data input and output.

4.0 MODEL CONSTRUCTION

The following sections provide the basic framework around which the numeric groundwater flow model was constructed.

4.1 Model Domain

The model domain used in this analysis is presented on Figure D-3. The model grid is centered on the new site of Limón de la Cerca and consists of 120 rows and 123 columns. The dimensions of the individual cells range from 25 by 25 meters (m) within the area of the site, to 500 by 500 m around the margins of the grid. The finer grid spacing was selected to provide a more refined depiction of conditions at the site. Larger cells were used beyond the project area where hydrologic information was not known. The grid has been oriented so that the X-axis of the grid parallels primary groundwater flow direction within the upper aquifer. The model grid superimposed over the project area is presented on Figure D-4.

As presented earlier, the hydrostratigraphic setting beneath the study area is characterized by an aquifer system comprised of mud flow, alluvial, fluvial, igneous, and volcanic deposits. Vertically, the grid consists of three layers:

- Layer 1- Upper Alluvial Aquifer
- Layer 2- Upper Bedrock Aquifer
- Layer 3- Lower Bedrock Aquifer

The elevations of the upper surfaces of each of these horizons are based on digital elevation data. The elevation data was then interpolated to individual cells to represent thickness of the hydrostratigraphic units within the groundwater flow. Elevations of the lower surface of each horizon were estimated by subtracting layer thickness from upper surface elevations. Layer 1 is calculated to be 30 m thick, layer 2 is 50 m thick, and layer 3 is 70 m thick.

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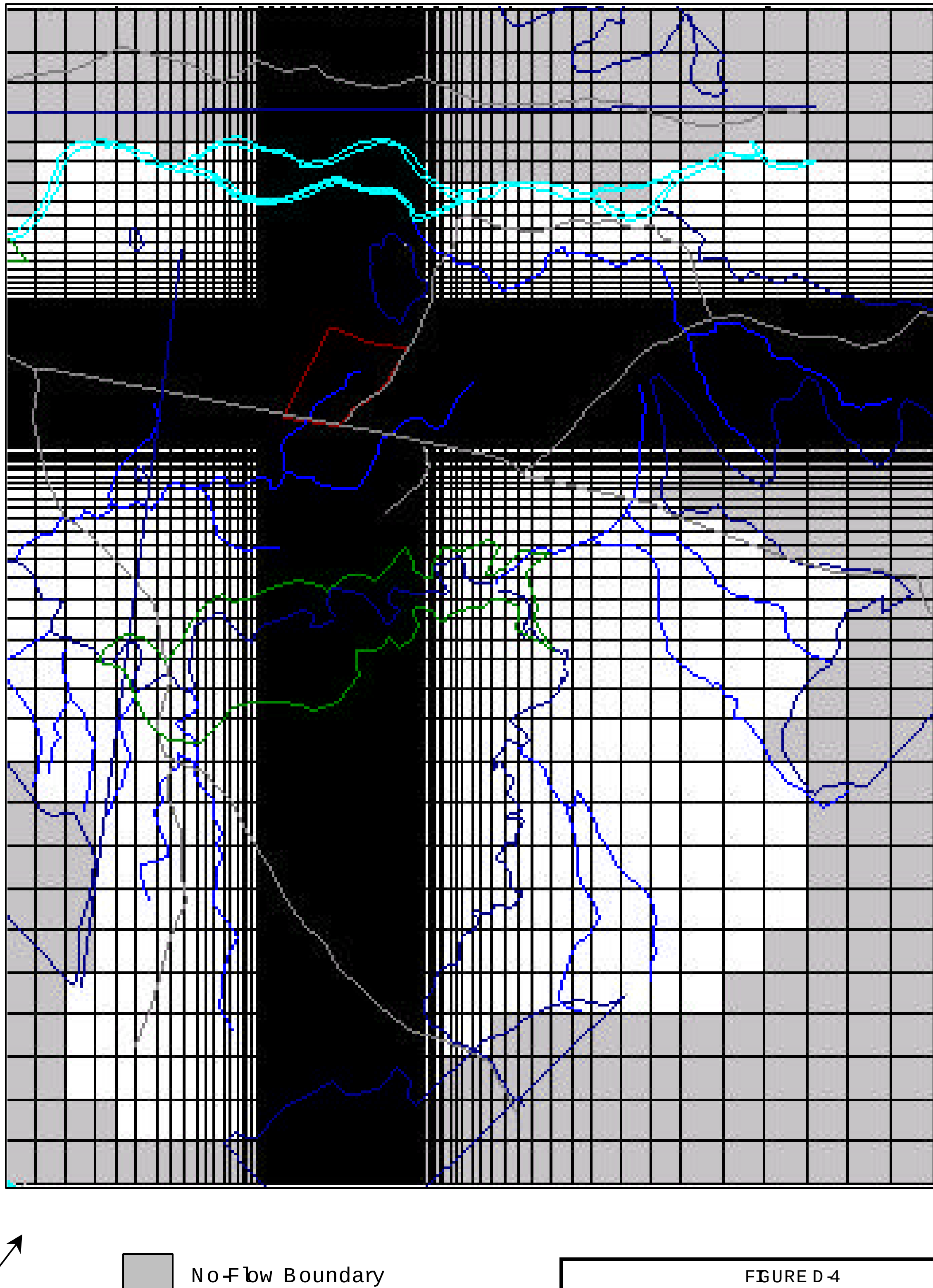

FIGURE D-4

MODEL GRID

Limón de la Cerca, Honduras
USAID

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4.2 Hydraulic Parameters

Layer 1 of the model simulates groundwater flow within the upper alluvial aquifer as it is associated with the site. This layer represents the total thickness of alluvial materials. The thickness of the Upper Alluvial aquifer is estimated to be 30 meters. Given the variable nature of the alluvial sediments and variable hydraulic conductivities associated with each sediment type, a hydraulic conductivity of 0.6 m/day was chosen for the entire layer (Figure D-5).

Layer 2 represents groundwater flow within the Upper Bedrock aquifer. The thickness of the Upper Bedrock aquifer is estimated to be 50 meters. Figure D-6 represents the hydraulic conductivity in layer 2. Hydraulic conductivity values for fractured bedrock materials are lower than the alluvium, and range from 0.023 m/day in the vicinity of LC-3, 0.2 m/day in the vicinity of BCLC-3, and 25 m/day in the vicinity of LC-4.

Layer 3 represents groundwater flow within the Lower Bedrock aquifer and is designated as a separate layer due to less rock fracturing observed at this horizon. The thickness of the Lower Bedrock aquifer is estimated at 70 meters. Figure D-7 represents the hydraulic conductivity in layer 3. Hydraulic conductivities ranged from 0.0023 m/day in the vicinity of BCLC-2 to 0.1 m/day in the vicinity of BCLC-1.

4.3 Sources and Sinks

The following sections outline and discuss the sources and sinks identified and used for this numeric groundwater model.

4.3.1 Rivers. The Choluteca River is considered to be the primary discharge area, and the Simpile River as the secondary discharge area for model layer 1. These discharge areas were simulated using "river nodes" for cells. An average elevation of the river surface water (specified head) in these cells was obtained from the topographic map of the area. The river nodes are presented on Figure D-8.

4.3.2 Recharge. As mentioned previously, the Choluteca valley receives between 1 and 1.8 meters of precipitation annually. Approximately 45,000,000 m^2 was estimated to represent the upland recharge area associated with the model domain. Assuming a 1 percent infiltration rate, an estimated 1,665 m^3/day is recharging to the aquifer system from the upland areas. This is represented in the model as flux boundaries along the margins of the upland areas. The flux boundary remains consistent in all three layers and is shown in Figure D-9. The 1,665 m^3/day of recharge water was distributed among the flux boundaries located in layers 1, 2, and 3. A recharge value of 3.75×10^{-5} m/day was assigned to the uppermost active layer in the model, which represents approximately 0.5 present of the total precipitation for the area.

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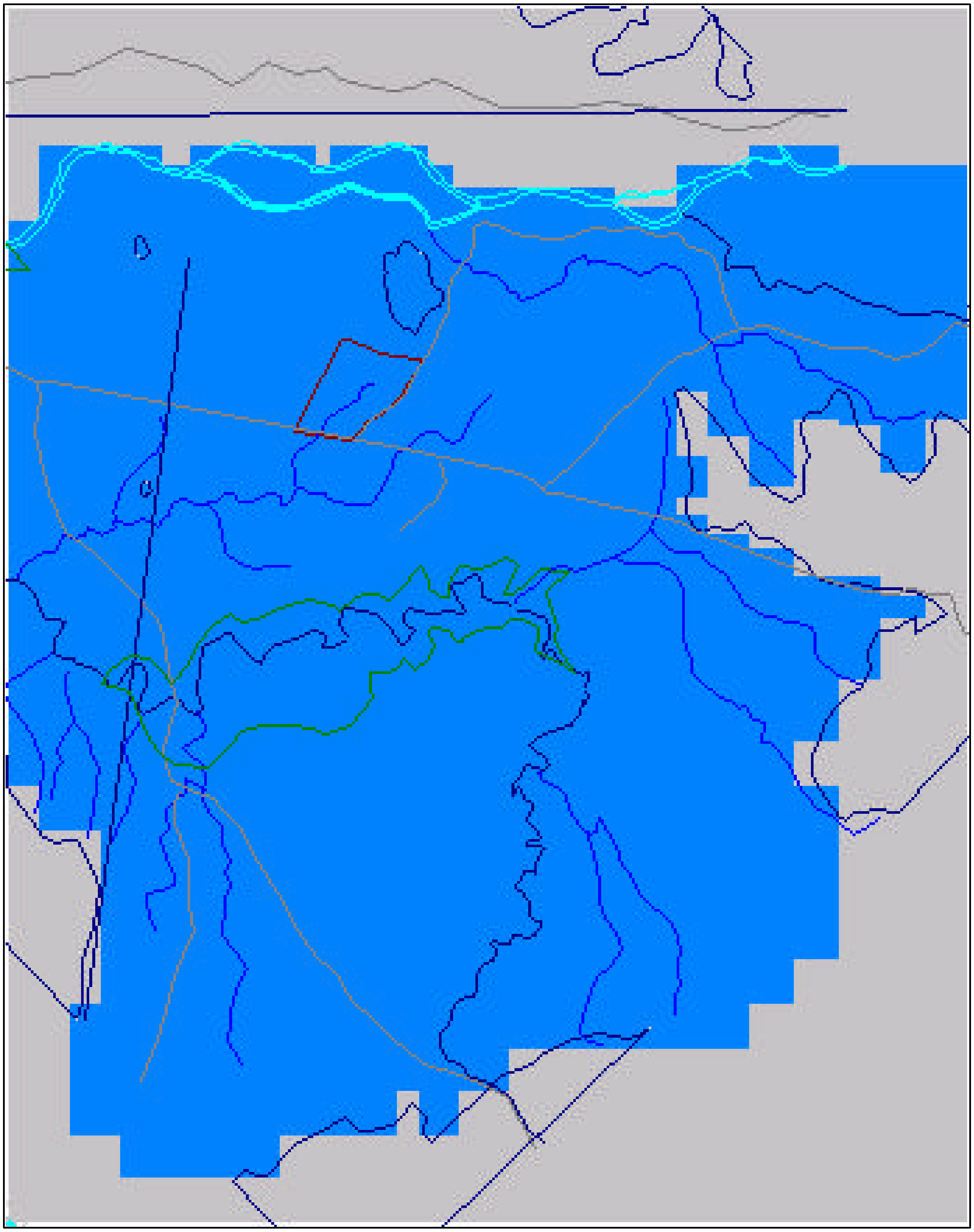

North

	No-Flow Boundary
	K=0.6 m/day Leakance = 0.0006 m/day

FIGURE D-5

LAYER 1 HYDRAULIC CONDUCTIVITY (K) AND LEAKANCE

Limón de la Cerca, Honduras

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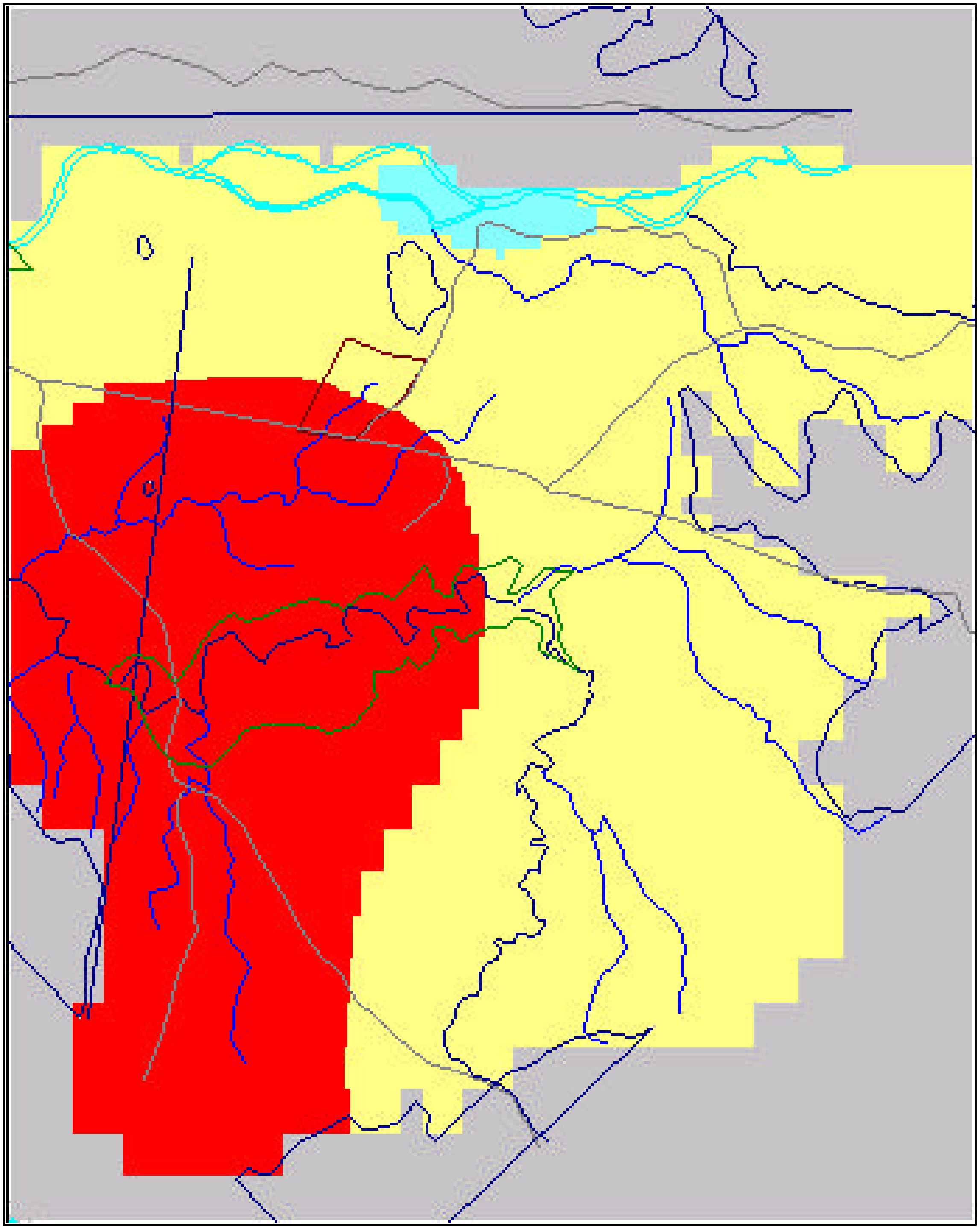
*Not to Scale



North

	No-Flow Boundary
	K=0.023 m/day Leakance = 0.00023 m/day
	K=25 m/day Leakance = 0.025 m/day
	K=0.2 m/day Leakance = 0.0002 m/day

*Not to Scale

FIGURE D-6

LAYER 2 HYDRAULIC CONDUCTIVITY (K) AND LEAKANCE

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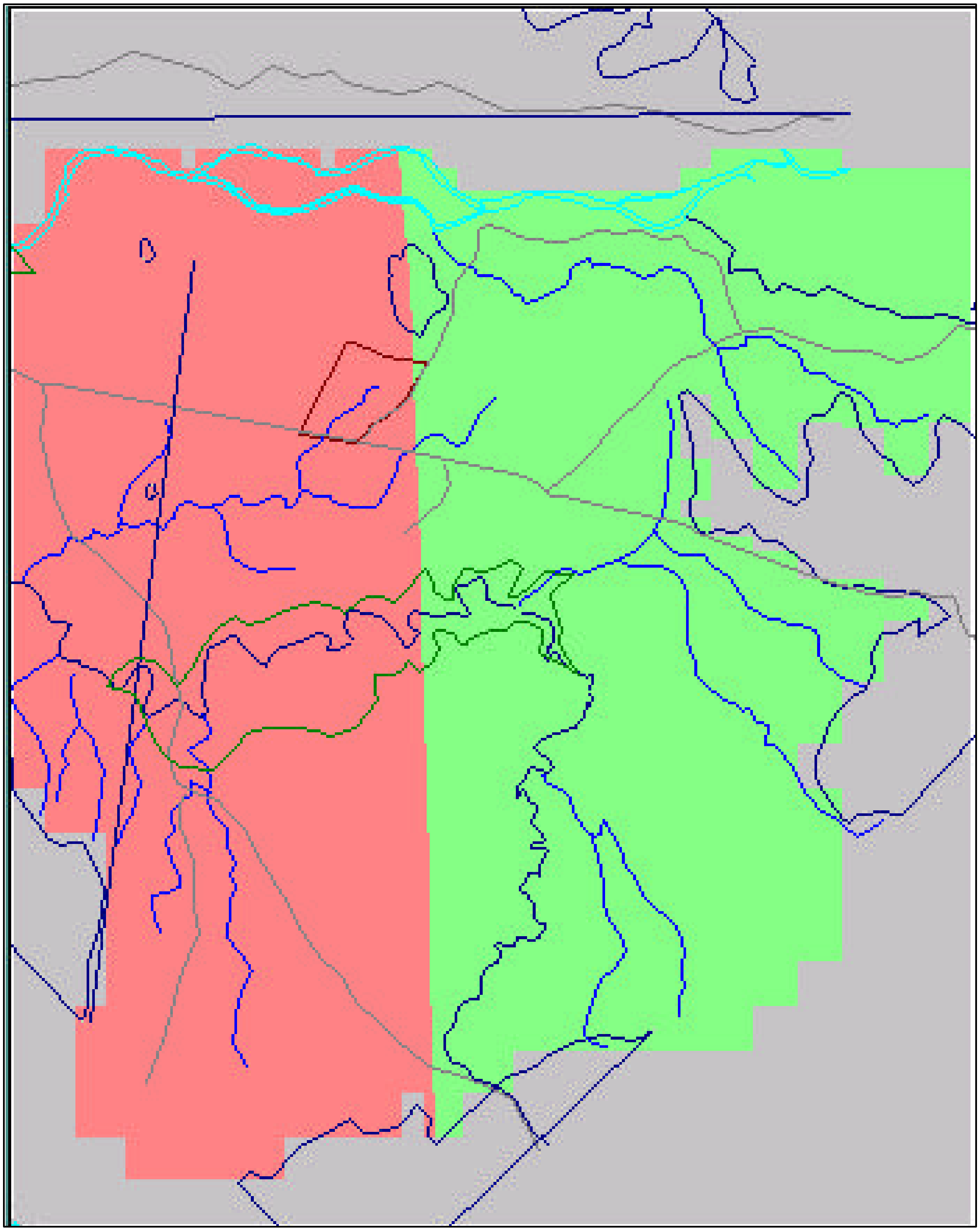

North

No-Flow Boundary

K=0.0023 m/day
Leakance = 0.000023 m/day

K=0.1 m/day
Leakance = 0.0001 m/day

*Not to Scale

FIGURE D-7

LAYER 3 HYDRAULIC CONDUCTIVITY (K) AND LEAKANCE

Limón de la Cerca, Honduras
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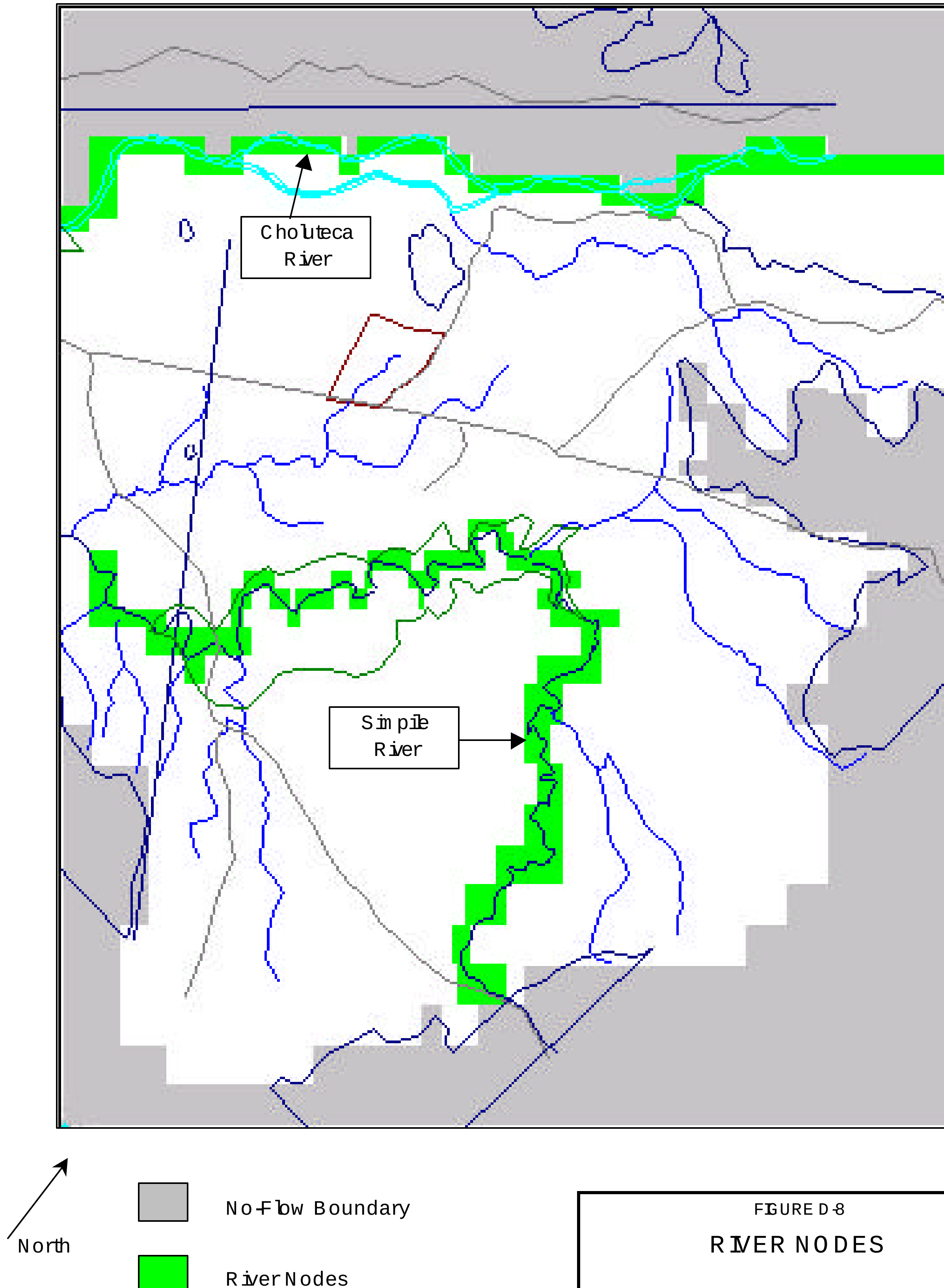

FIGURE D-8

RIVER NODES

Limón de la Cerca, Honduras
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*Not to Scale

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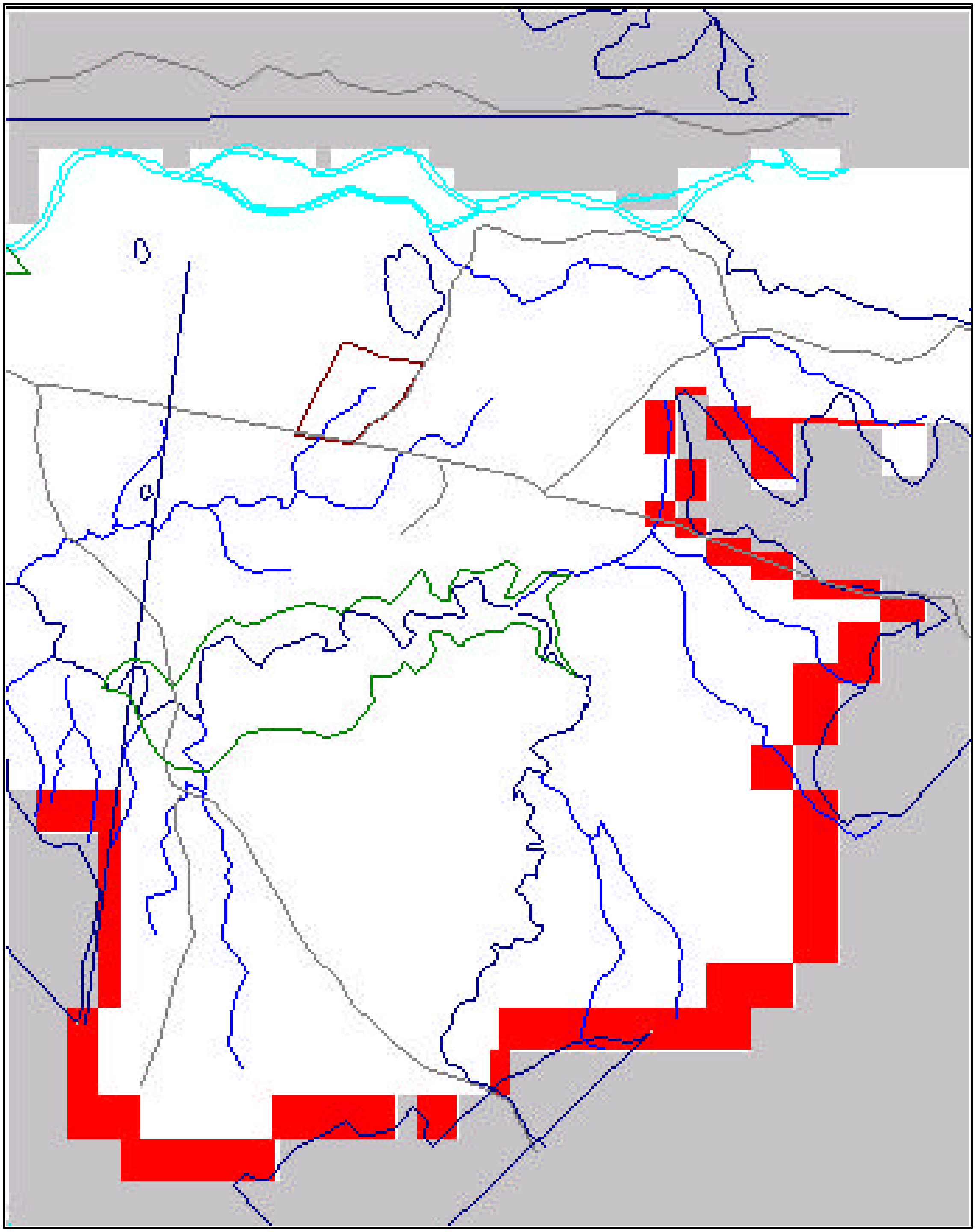

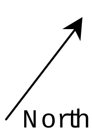

Flux Boundary

No-Flow Boundary

FIGURE D-9

FLUX BOUNDARY FOR LAYERS 1, 2, AND 3

Limón de la Cerca, Honduras

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*Not to Scale

4.3.3 Wells. Wells, LC-1, LC-2, LC-3, and LC-4 were identified at Limón de la Cerca as possible influences on groundwater conditions at the site within the Upper Alluvial and Upper Bedrock aquifers. These four wells are used for domestic water purposes. After the initial "base case" model was set-up, pumping rates of 44 m^3/day, 273 m^3/day, 44 m^3/day, and 364 m^3/day were assigned to wells LC-1, LC-2, LC-3, and LC-4, respectively. These rates are based on the knowledge that the wells are pumping intermittently throughout the day.

4.4 Boundary Conditions

The following sections discuss the boundary conditions existing in the numeric groundwater model.

4.4.1 No-Flow Boundaries. The uplands comprised of a variety of igneous rocks along the eastern and southern boundaries of the area are simulated as no-flow boundaries as well as all cells northeast of the Choluteca River. The no-flow boundaries are indicated on Figure D-3.

4.4.2 General Head Boundaries. The northeast and southwest perimeter is simulated using "general head" boundary (GHB) cells. These boundary cells simulate the extension of the aquifer beyond the model boundary by allowing water to enter or exit the model domain as a function of the local gradient, transmissivity, and cell dimensions. The specific head values used were estimated by projection of groundwater elevation data and topographical information. The general head boundaries are presented in Figure D-10.

4.5 Selection of Calibration Targets

Nine calibration targets corresponding to existing wells were chosen within the site area. Head was measured at each of these targets, since static water levels were available. Water levels across the site have been measured sporadically since May 2001. An average water level was chosen to represent the target calibration in the model. The nine calibration targets include the following: wells LC-1, LC-2, LC-3, LC-4, BCLC-1, BCLC-3, Sr. Victor Argueñal, Sr. Pacheco, and Col. Marcelino Chanpagnat. Figure D-1 shows the location of these target wells. Table D-3 shows the water levels of the nine calibration targets.

Table D-3. Calibration Targets

Calibration Target Name	Water Level (m)
LC-1	51.97
LC-2	54.05
LC-3	51.39
LC-4	50.81
BCLC-1	54.70
BCLC-3	47.90
Sr. Victor Argueñal	50.77
Sr. Pacheco	50.36
Col. Marcelino Chanpagnat	46.88

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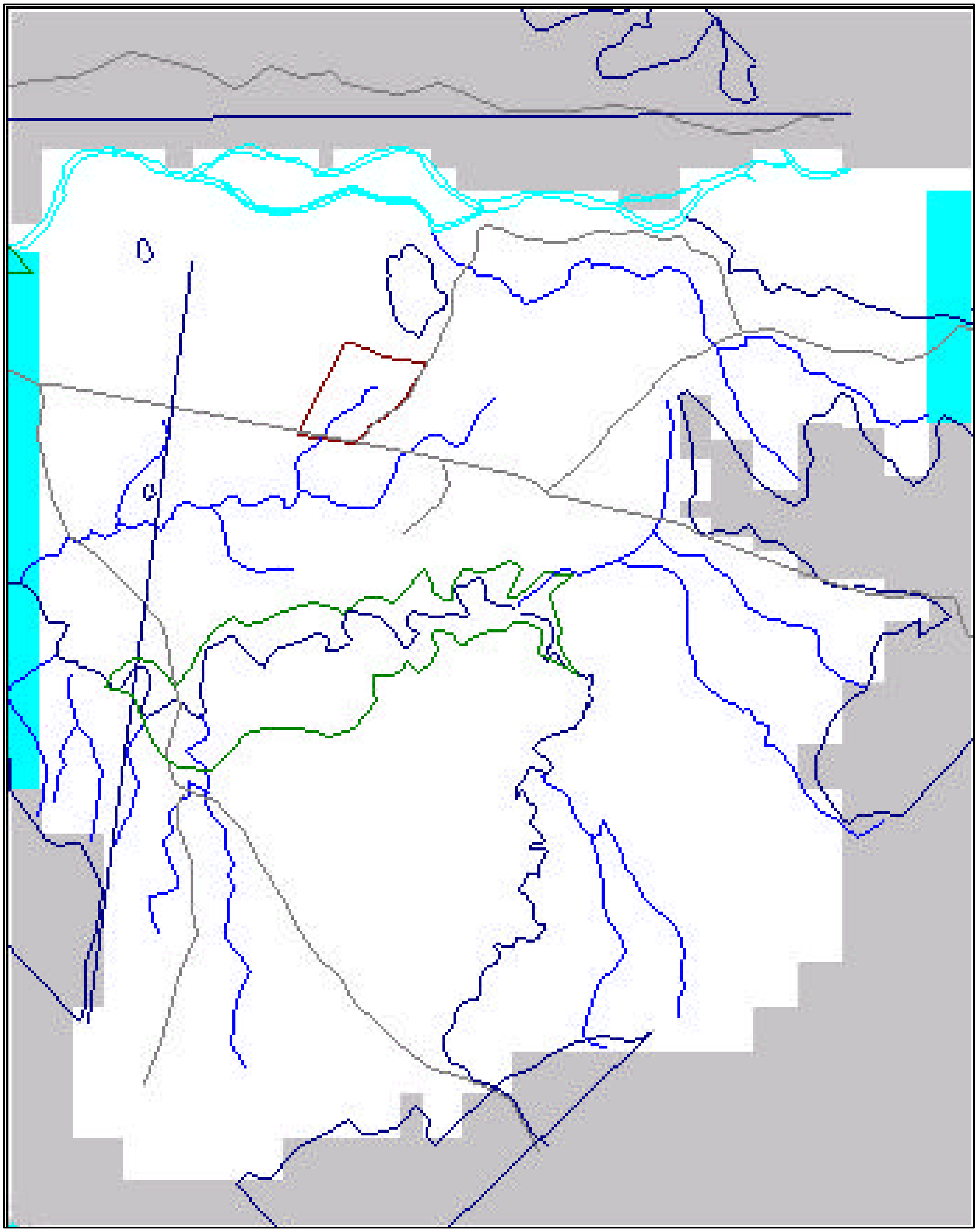

North

General Head Boundary

No-Flow Boundary

FIGURE D-10

GENERAL HEAD BOUNDARIES FOR LAYERS 1, 2, AND 3

Limón de la Cerca, Honduras

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*Not to Scale

5.0 CALIBRATION

For this report, the term calibration refers to the standard approach of matching measured heads to model heads at steady-state conditions and adjusting input parameters within reasonable limits until an acceptable match is achieved.

5.1 Qualitative and Quantitative Analyses

The first step in the calibration process is the selection of initial input parameters. The values used for the initial run were obtained from previous and ongoing investigations. Once the initial input parameters were selected, the initial base case simulations were conducted and results were evaluated using a head residual analysis. A head residual is the difference between the measured head in a well and the model-predicted head in the cell that represents the location and depth of the well. Positive residuals indicate the predicted head is lower than the measured value, whereas negative residuals indicated the predicted head is higher than the measured value. The sum of the residuals is an indicator of an overall bias (heads generally too high or too low) in the prediction. If, for example, the predicted heads were quite close to the measured heads but most were slightly higher, this term would be elevated in the negative direction. The average of the absolute residuals is and indicator of the accuracy of the match and, as a rule, should be less than 10 percent of the steady-state head change across the project area.

During the steady-state calibration process, the various input parameters were adjusted within reasonable limits and the results noted. This process was continued until an acceptable match was made with averaged head values. Table D-4 presents the results of the calibration simulation. The overall sum of residual is 28.9 m, with an average absolute residual of 1.18 m. The sum of residual in layer 1 is1.68 m, with an average absolute residual of 1.30 m. The sum of residual in layer 2 is 26.3 m, with an average absolute residual of 1.36 m. The sum of residual in layer 3 is 0.955 m, with an average absolute residual of 0.59 m. Considering the complexity of the aquifer system these calibration results are reasonable matches to our understanding of the field conditions. The calibrated modeled groundwater elevations for layer 1 through 3 are presented in Figure D-11 through Figure D-13, respectively.

Table D-4. Calibration Statistics

Calibration Statistics	m
Residual Mean	-0.75
Residual Standard Deviation	1.63
Residual Sum of Squares	28.9
Absolute Residual Mean	1.18
Minimum Residual	-3.62
Maximum Residual	0.95
Observed Range in Head	7.82
Residual Std. Dev./Range	0.208

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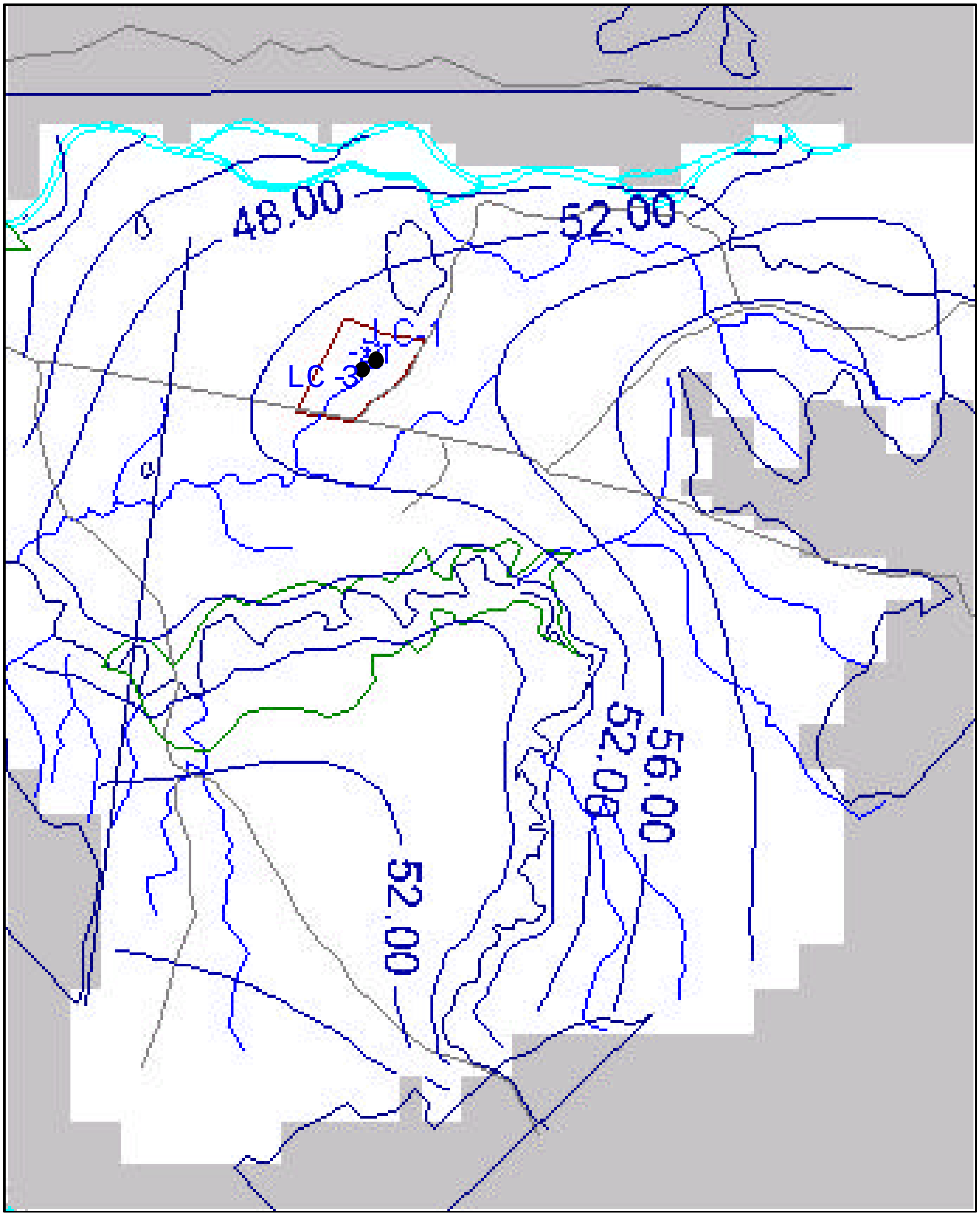

North

No-Flow Boundary

Potentiometric Surface Lines
Contour Interval = 4 meters

● LC-1 Calibration Target/Well

*Not to Scale

FIGURE D-11

LAYER 1 HEADS

Limón de la Cerca, Honduras
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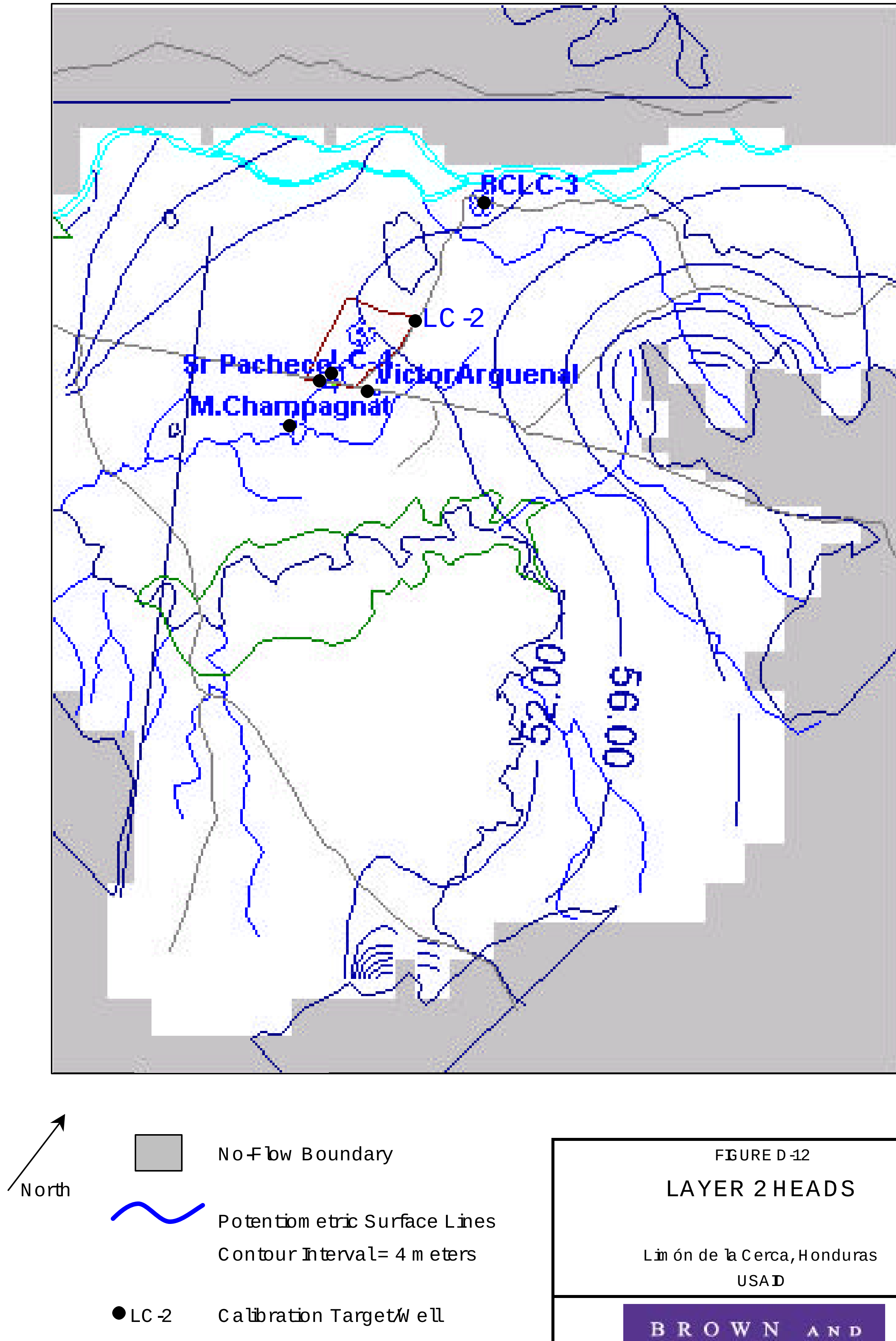

*Not to Scale

FIGURE D-12

LAYER 2 HEADS

Limón de la Cerca, Honduras
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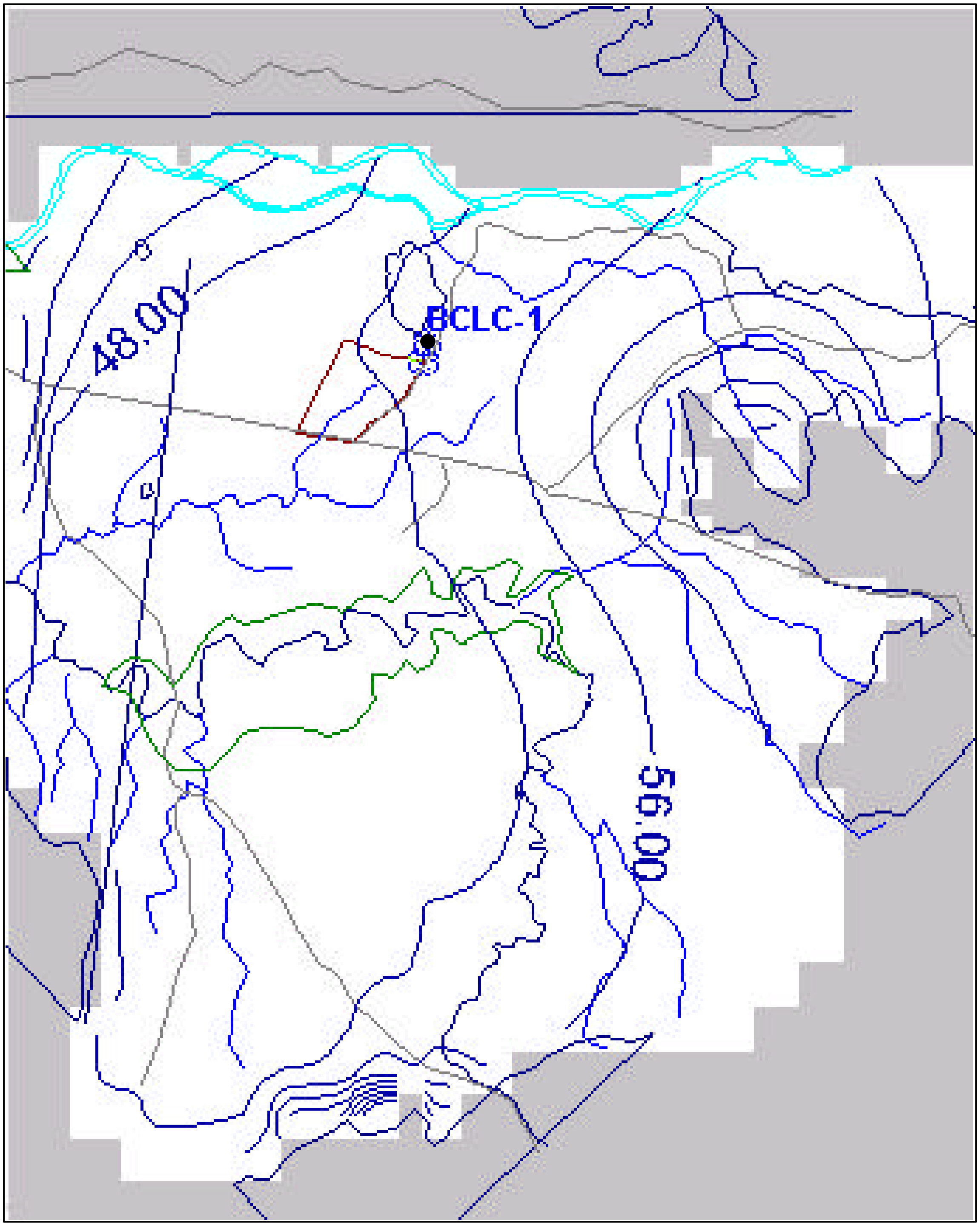

North

No-Flow Boundary

Potentiometric Surface Lines
Contour Interval = 4 meters

● BCLC-1 Calibration Target/Well

*Not to Scale

FIGURE D-13

LAYER 3 HEADS

Limón de la Cerca, Honduras
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5.2 Sensitivity Analysis

A sensitivity analysis was performed to evaluate the sensitivity of the model output to uncertainties inherent in the input data. The first step in this process was to establish reasonable ranges within which to vary the input parameters. Where ranges of values were available based on field data, the upper and lower values were used. Otherwise parameter values were increased and decreased to represent upper and lower limits. The sensitivity analysis was conducted by varying one input parameter at a time, and comparing the predicted steady-state match with that of the calibrated base case simulation.

The results of the sensitivity analysis indicate that for the site as a whole, the most sensitive parameter in the model is aerial recharge. Aerial recharge is defined as rainfall and its subsequent infiltration into the ground. The flux boundary was very sensitive as the flux value increased. A decrease in value did not yield exceptionally different results.

6.0 PREDICTIVE SIMULATIONS

The current groundwater flow model was not used to predict potential groundwater resources due to the complexity of the hydrogeology/geology and the uncertainty of accurately depicting the conceptual hydrogeologic model for the site. However, a "pumping case" scenario was modeled using the initial "base case" model and the five existing production wells. The wells were pumped at varying rates as described in Section 4.3. The potentiometric surface changed slightly by approximately 1-2 meters in all three layers; although this had no change on the general trend of groundwater flow through the valley. The modeled heads of the "pumping case" scenario in Layer 1, 2, and 3 are presented in Figure D-14, Figure D-15, and Figure D-16, respectively.

7.0 SUMMARY AND CONCLUSIONS

The modeling process produced a preliminary groundwater flow model that serves to support the understanding of existing hydrogeologic conditions. The original intent of the model was for use in the evaluation of potential groundwater resources. However, due to the complexity of the geology/hydrogeology and the uncertainty of accurately defining the conceptual hydrogeologic model for the site, use of this groundwater model should be limited to developing a general understanding of potential groundwater resources for the community. The information data collected to date, the conceptual geologic/hydrogeologic model developed for the site, and the results of the groundwater water flow model should be used as the basis for an initial understanding of the site.

Increasing the groundwater flow model's effectiveness to be used as a tool to manage the community of Limón de la Cerca's groundwater resources can only be achieved by optimizing the conceptual and groundwater flow model through the collection of additional geologic and hydrogeologic information. With this additional geologic and hydrogeologic information, the usability of the model will increase.

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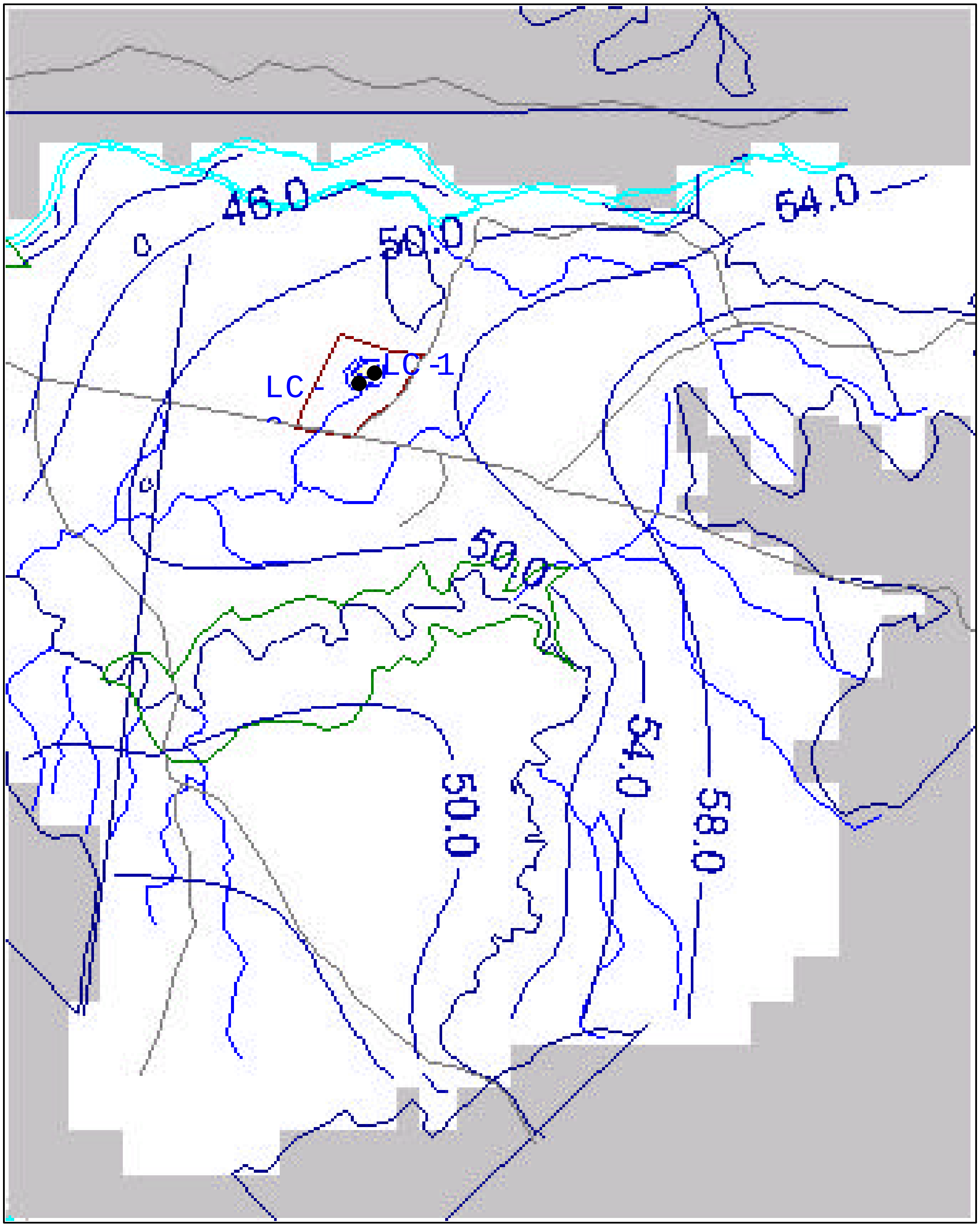

North

No-Flow Boundary

Potentiometric Surface Lines
Contour Interval = 4 meters

● LC-1 Calibration Target/Well

*Not to Scale

FIGURE D-14

LAYER 1 HEADS
PUMPING CASE SCENARIO

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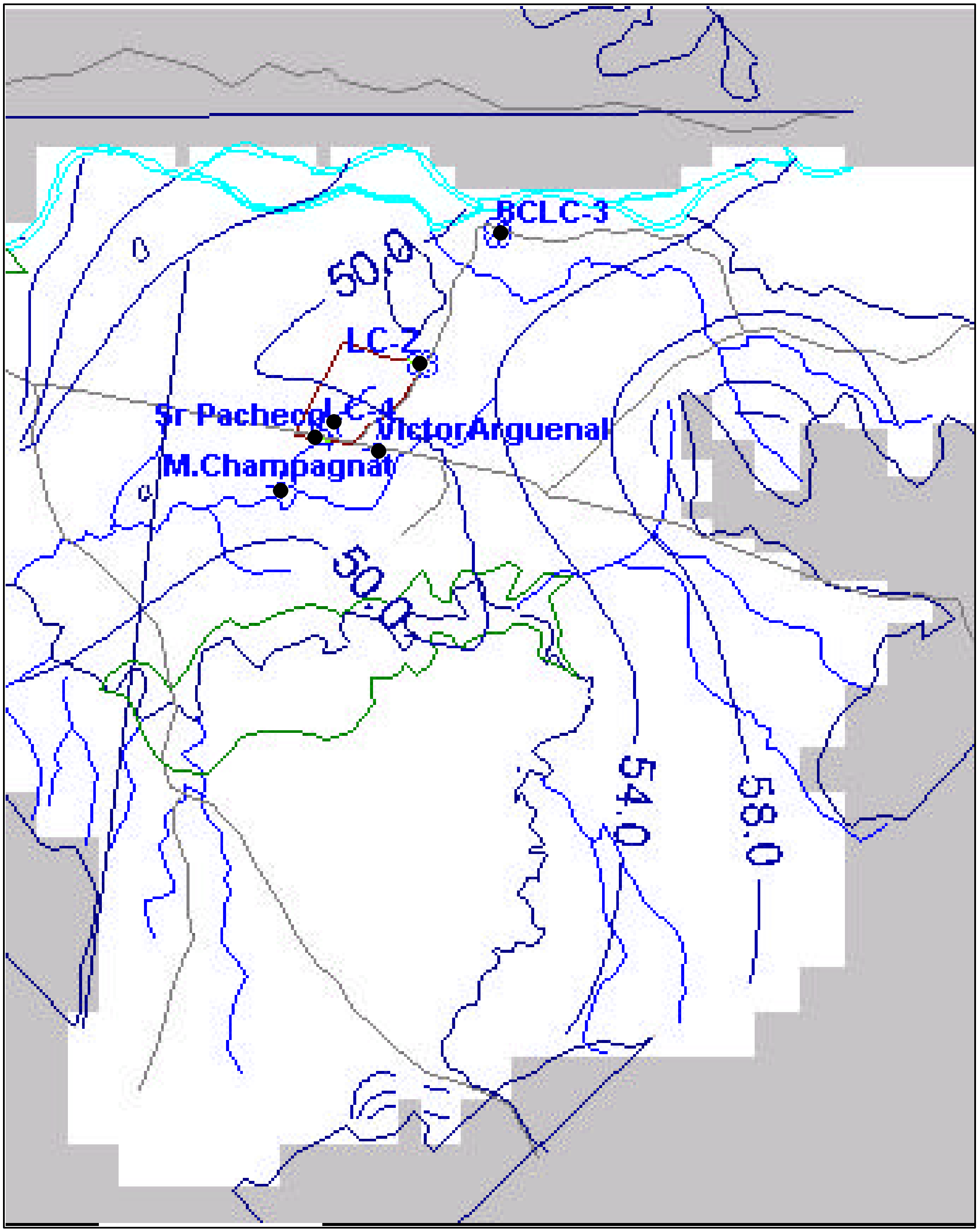

No-Flow Boundary

Potentiometric Surface Lines
Contour Interval = 4 meters

● LC-2 Calibration Target/Well

*Not to Scale

FIGURE D-15

LAYER 2 HEADS
PUMPING CASE SCENARIO

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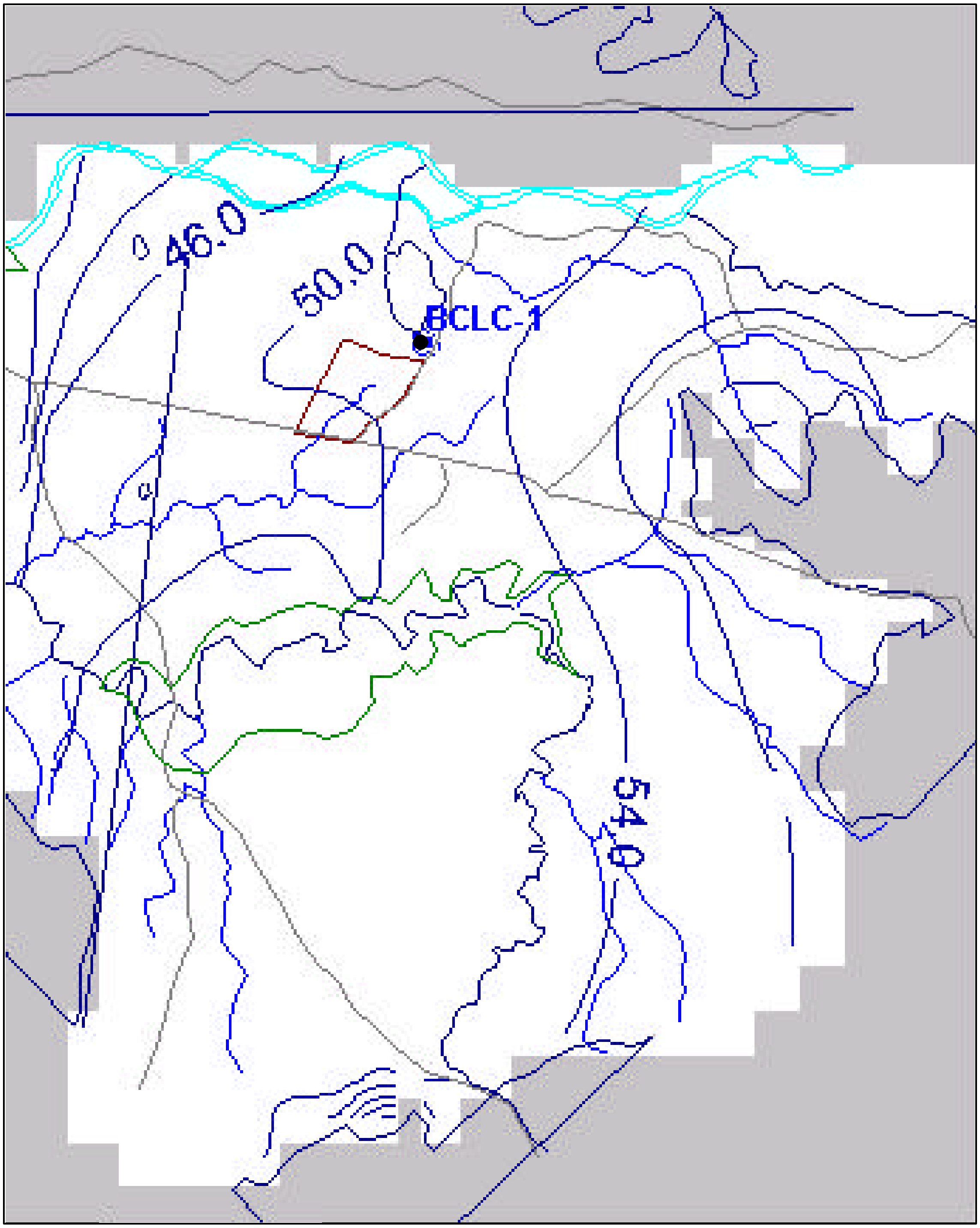

No-Flow Boundary

Potentiometric Surface Lines
Contour Interval= 4 meters

● BCLC-1 Calibration Target/Well

*Not to Scale

FIGURE D-16

LAYER 3 HEADS
PUMPING CASE SCENARIO

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8.0 REFERENCES

Environmental Simulations, Inc., 1997. Groundwater Vistas.

Flores Molina, M.E., 1999. Ubicacion de Nuevos Sitios de Perforacion de Pozoz de Investigacion/Produccion. Urbanizacion Limón de la Cerca (Nueva Chloluteca), Choluteca, Choluteca.

McDonald, M.G. and Harbaugh, A.W., 1988. A Modular Three-dimensional Finite-Difference Groundwater Flow Model, United States Geological Survey Techniques of Water-Resources Investigations, Book 6, Chapter A1.

SERPE, date unknown, Well construction diagram for LC-4.

APPENDIX E

Water Resources Management System Users Guide

WATER RESOURCES MANAGEMENT SYSTEM USER'S GUIDE

Limón de la Cerca, Honduras

June 2002

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The Water Resources Management System (WRMS) is a desktop computer application developed to store, manage, and analyze technical information gathered and generated for this project. The application is a management tool that can be used by the municipalities and other decision-makers to sustain and manage their groundwater resources. The system is composed of both a data management system and a geographic information system linked together as one application. Through the WRMS, users can:

- Manage and generate reports for wells, storage tanks, and springs
- View well logs and well completion diagrams
- Analyze water quality and water level data
- Track statistics on water use
- View wells, water quality information, and aquifer characteristics on maps of the study area
- Identify and prioritize future well sites

The application consists of two primary components; a data management system and a geographic information system (GIS). The application is written so that the two components work together and function as one system. Data are shared back and fourth between the data management system and the GIS.

1.1 Overview

The WRMS consolidates the most critical water resource information for a municipality. It provides a central place to manage, analyze, and display water resource information in both map and tabular form. The WRMS accommodates all major types of information needed for sound water resource management including data on wells and other water sources, future demand and growth, infrastructure and organizational boundaries, and water quality and aquifer characteristics.

Because the system is designed to accommodate additional data as more information is collected and wells are created or modified in the future, it can be used to facilitate sound water resource decision-making in the future. Is easy to use and requires minimal training, which will facilitate continued system use. It uses a standard methodology for identifying and prioritizing future well sites, which will allow municipalities to continue to apply a consistent planning approach.

The WRMS is designed to work in conjunction with the findings of the Water Resources Management Report. Most of the data collected or developed for the report are contained in this system, and are available for further analysis, display, and incorporation with new data as it is collected. The system can be used to view and explore additional details of the existing water system, as well as explore in detail the conceptual model of the aquifer system and the groundwater modeling results.

The WRMS should be used to provide a common environment for communication among stakeholder agencies for water resource planning. The system provides a consistent view and methodology for analyzing water resource data. Consistently using it as a communication tool among stake-holders will make the sometimes confusing and complex technical information easier to understand. New data, such as new wells, additional sampling results, or new water level measurements should be entered into the system in order to have the most up-to-date information available for decision-making.

1.2 How to Use the Manual

This manual is divided into two parts:

- **Users Guide** – This section describes the application and use of the system from the users perspective. It explains the functionality of the system, presents step-by-step instructions for adding and managing data, creating reports, generating maps, and using the analysis tools. Anyone who needs to use the system should read this section to find the proper procedures for adding, managing, and analyzing data.

- **Administrators Guide** – This section describes the operation of the system and covers the procedures necessary to keep the system functioning properly. It is written for the person who is responsible for making sure the system is configured and operating properly.

2.0 USER GUIDE

This section explains how the system can be used to manage, analyze, and report on water resource data. First the organization of the data will be discussed, and then an overview of the functionality of the interface will be explained. Finally, the user will be walked through a series of common tasks that are typically performed using the system.

2.1 Data Organization

Figure 2-1 shows how the data are organized in the WRMS. The data organization is presented in a hierarchy shown on the left. The types of data collected at each level are shown on the right. The highest level of data is at the Municipality level. All other data entered into the system will be associated with a Municipality. Information collected at this level includes map data in the GIS system and pre capita growth/water consumption statistics for each municipality.

Within each municipality, there will be one or more service areas. A service area is a self-contained portion of the distribution system. It is comprised of wells, storage tanks, piping, and other infrastructure designed to supply a specific portion of the municipality. Typically, it is self-contained, with its own operating characteristics[1]. The user can store water usage information for each storage area (e.g. population served, pressure, and water usage).

Within each service area, there may be one or more wells and storage tanks. Most of the information stored in the WRMS is related to wells. For each well, its construction, location, and operational specifications can be stored. Water sample records and water level records can be entered, and scanned images can be loaded (e.g. well completion diagrams, photographs, and well logs). For storage tanks, operational and construction specifications can be entered.

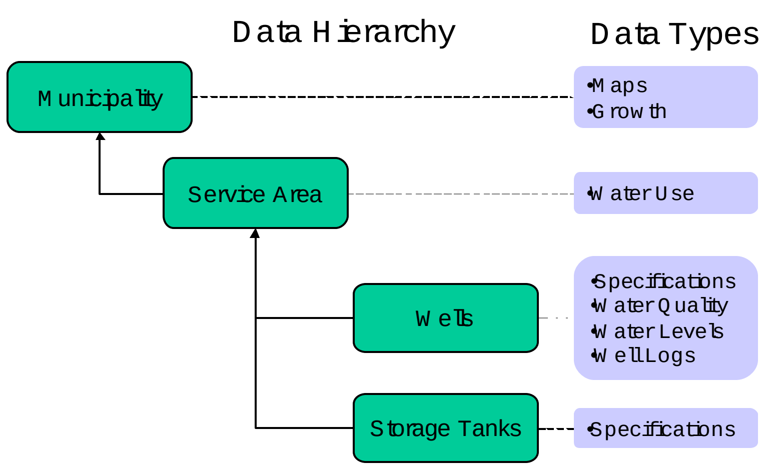

Figure 2-1. Data Organization

[1] This system is delivered with one service area defined for each municipality, which may or may not reflect the actual service area configuration for each municipality. The WRMS will work fine without changing this, however, the capability of redefining the service areas to more accurately reflect the conditions of each municipality is available. See Entering Infrastructure Data for more details.

2.2 User Interface

Once the application is started, the user is presented with a variety of options via the Main Menu at the top left-hand corner of the screen.

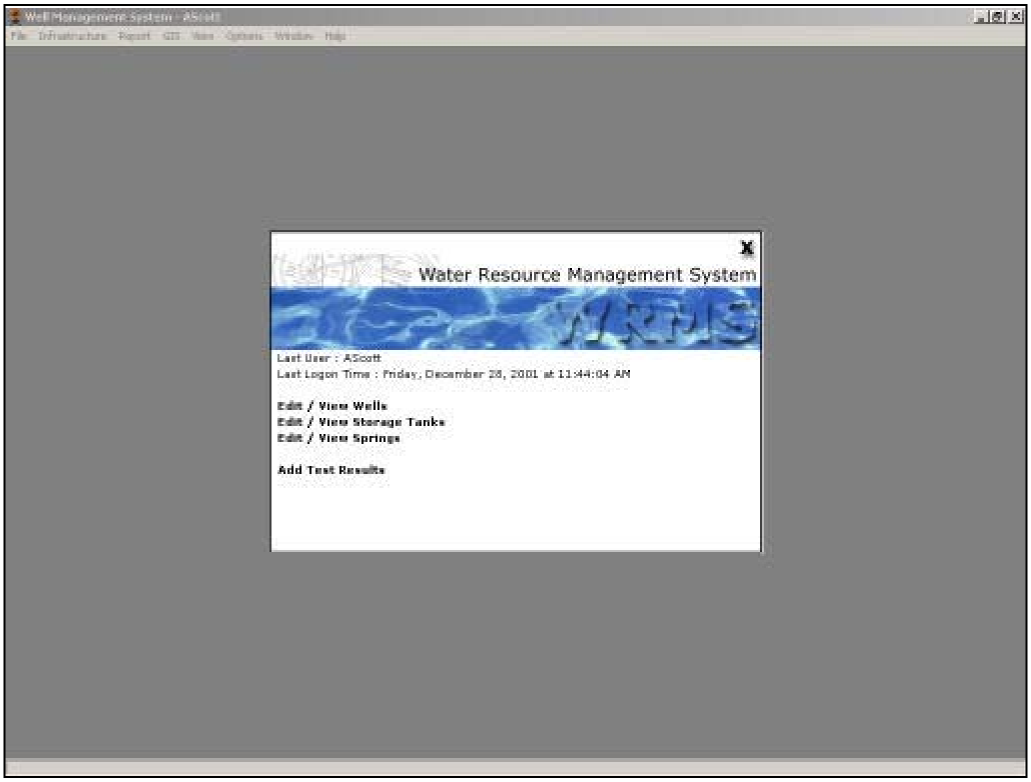

Figure 2-2. Startup Screen

The options available are:

- **FILE** – Exit the application.
- **INFRASTRUCTURE** – Used to manage data for the municipality, service areas, wells, and storage tanks.
- **REPORT** – Used to run reports and graphs for selected infrastructure data.
- **GIS** – Opens ArcView® to create maps or run the Well Site Prioritization tool.
- **VIEW** – Opens the USGS Database or the Water Resources Management Plan report.
- **OPTIONS** – Mostly an administrative area, it is where the user can change the language or to manage system configuration.
- **WINDOW** – Used to manage different application windows that are opened.
- **HELP** – Opens the help file for the WRMS.

2.3 Interface Terms

The following figure shows a typical interface screen and its components. The system functionality is selected via the **MAIN MENU** shown at the upper left-hand portion of the screen. Infrastructure components are navigated via the **DATA TREE** on the left. The **DATA TREE** allows the user to navigate through the infrastructure hierarchy. For example, each **MUNICIPALITY** contains a

SERVICE AREA, and each **SERVICE AREA** contains **WELLS** and **STORAGE TANKS**. Each element in the tree has a '+' box associated with it. Clicking on the '+' expands that branch of the tree. For example, clicking on the '+' next to **WELLS** opens a list of all wells within the selected **SERVICE AREA**. When the branch is expanded, the '+' symbol turns into a '-' symbol. Close the branch by clicking on the '-'. By expanding and contracting each branch, the user can quickly navigate to the desired information.

The area on the right is used to present information about the selected infrastructure element. In this example, the data entry screen for Well LC-1 is shown. This screen is composed of the following kinds of elements:

- **TEXT BOX**: Used for entering free-form text.
- **PICK LIST**: Used to make a select from a list. The lists are managed under **VALID VALUES** in the **OPTIONS** menu selection. See the Administrators Guide for more information.
- **CHECK BOX**: Represents a Yes (if checked) or No (if unchecked).
- **BUTTON**: Click on the button to initiate an action (e.g. Close the window, save data, etc.).

This terminology will be used throughout this Users Guide.

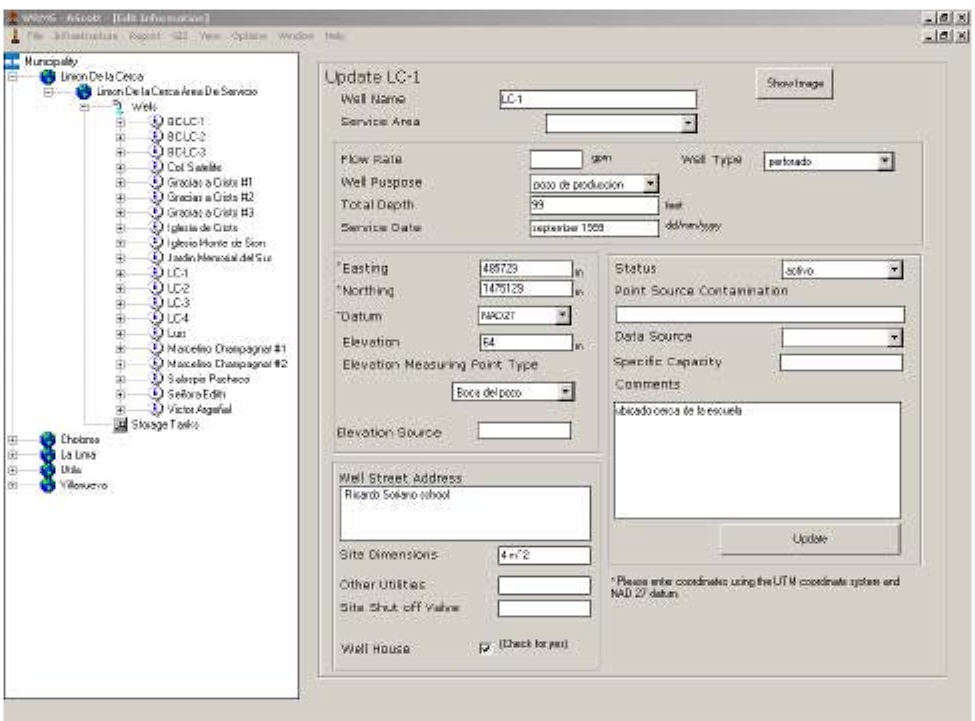

Figure 2-3. Interface Terms

Two additional terms are needed associated with the mouse-pointing device:

- **CLICK** – When instructed to click on something, point the arrow on the screen over the object and click the *left* mouse button.

- **RIGHT-CLICK** – When instructed to right-click, point the arrow on the screen over the object and click the *right* mouse button.

2.4 Common Tasks

This section describes the common tasks that can be performed using the WRMS. These are:

- Opening the application – How to start the WRMS.
- Changing the Interface Language – The WRMS interface can be translated between Spanish and English.
- Managing Infrastructure Data – Entering and managing data related to Municipalities, Service Areas, Wells, and Storage Tanks.
- Creating Reports – Generating standard reports for infrastructure data.
- Map Analysis – Using ArcView® to generate maps.
- Well Site Prioritization – Using the well site prioritization decision-support tool.
- Assessing Related Information – Opening up other applications.
- Getting Help – Accessing this manual on-line.

2.4.1 Opening the Application. This application comes already installed on the computers provided. To start the WRMS, do the following:

1. Click on the **START** button in the bottom left-hand corner of the screen to open the system menu.
2. Click on **PROGRAMS**. This will open a sub-menu of available programs and program folders
3. Click on on **WRMS**. The application will open when WRMS is clicked.

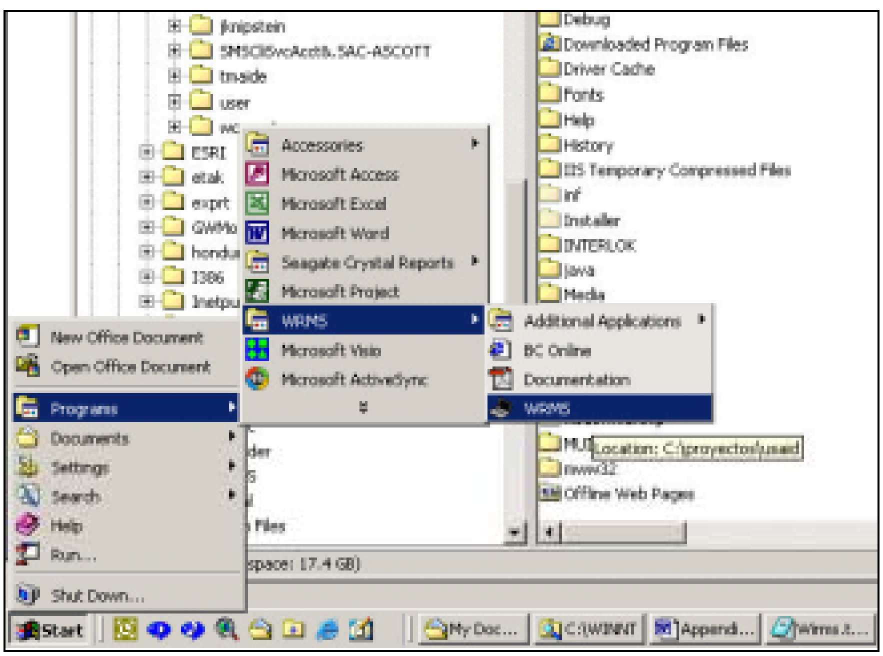

Figure 2-4. Starting the WRMS

2.4.2 Changing the Interface Language. The user may change the language used in the WRMS interface. To do this:

1. Click on **OPTIONS** from the menu. A sub-menu will appear.
2. Click on language from the sub-menu.
3. A pop window will appear with a list of available languages. Select the language desired and click **OK**.

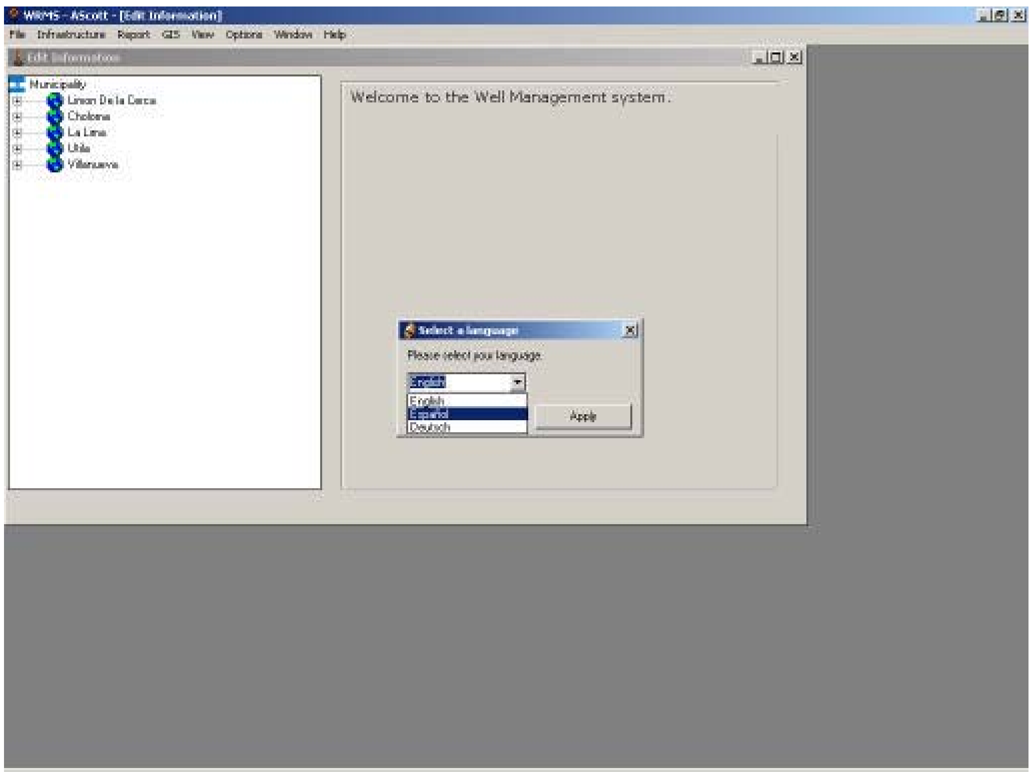

Figure 2-5. Changing the Language

The interface will be translated into the selected language.

Note: It may be necessary to close a window and re-open it for the translation to take effect. Also, if a phrase is not translated, it means that the translation has not been entered into the translation database. Please see the Administrators Guide for the steps to add a new translation.

2.4.3 Managing Infrastructure Data. Infrastructure data includes information on municipalities, service areas, wells, and storage tanks. These data are organized in a hierarchy in the database (see Data Organization, above) and are presented the same way in the user interface. To access the data entry and management screens:

1. Click on **INFRASTRUCTURE** from the **MAIN MENU**. A sub-menu for **WELLS** and **STORAGE TANKS** will appear.
2. Click on **WELLS** or **STORAGE TANKS**.

Selecting **WELLS** or **STORAGE TANKS** will open the **DATA TREE** and expand the desired branch of information. The first element of the desired type (either the first well or first storage tank) will be shown, presenting the general information for that particular record on the right. The user may then change or review any of the information associated. If data are changed, click on the **UPDATE** button to save the changes.

To navigate through the data, click on the desired branch. The branch will expand to the next level, allowing the user to view its contents. Depending upon the level selected, a data form will appear on the right. The table below shows the information provided at each level.

Table 2-1. Data Screens for Each Level

Level	Data Shown
Municipality	Growth and Water Consumption
Service Area	Service Area Characteristics
Wells	Well Depth Graph
Individual Wells	Well General Information
Individual Storage Tanks	Storage Tank General Information

2.4.3.1 Municipalities. Municipalities are the study areas defined for this project. Typically, they incorporate the urban and developed areas of a community, but may not include the entire municipal boundary. When a **MUNICIPALITY** is selected from the **DATA TREE**, water consumption data will be shown on the right. This is a simple table showing per-capita consumption per year. To enter a new record, click on the empty row on the bottom of the table. Enter the year, estimated population, and the average per-capita water consumption in gallons per day per person. The table can accommodate historical data as well as predicted growth. This information enables the user to view expected water consumption patterns over time.

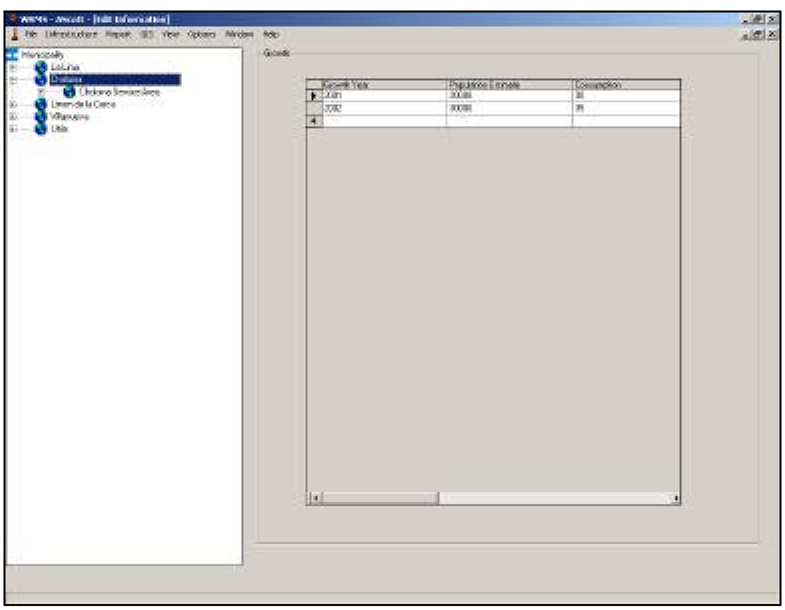

Figure 2-6. Predicted Growth Data Screen

2.4.3.2 Service Areas. To create a new **SERVICE AREA** for a **MUNICIPALITY**:

1. Click on the **MUNICIPALITY** desired, then right-click to bring up a popup menu.
2. Select **ADD SERVICE AREA**. A blank service area form will appear.

Enter the service area name and other data as desired, then click **UPDATE**. The **DATA TREE** will insert the new **SERVICE AREA**.

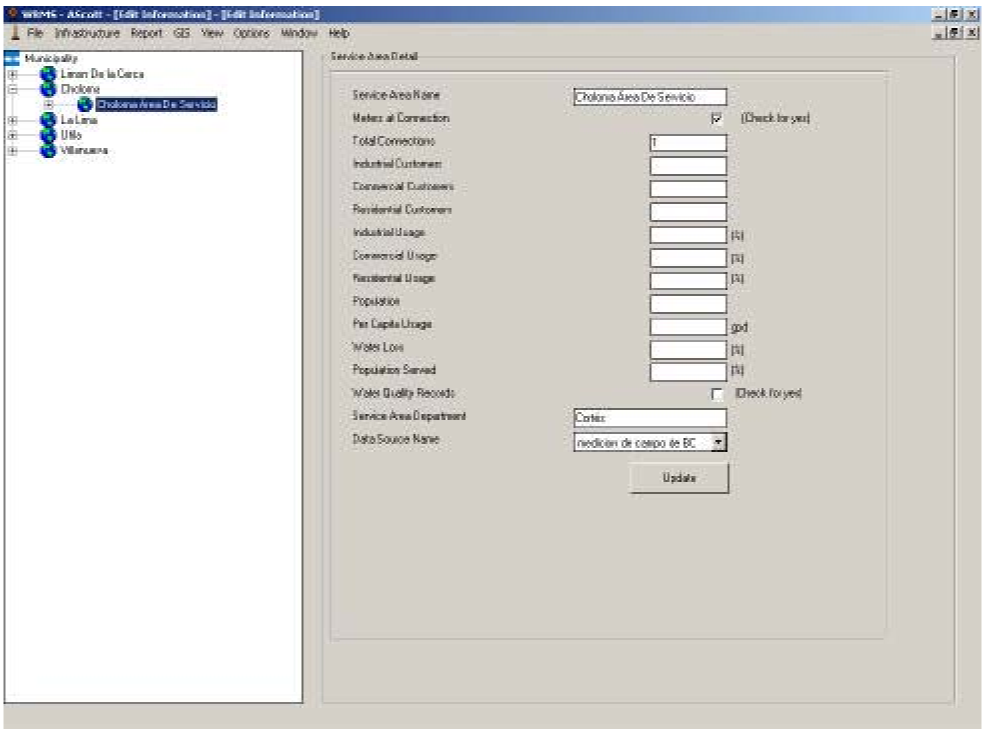

Figure 2-7. Service Area Data Screen

Clicking on an existing **SERVICE AREA** brings up a form displaying water consumption information for the area selected. This information can be entered for each service area for quick reference when evaluating service area needs. The following table describes the service area information:

Table 2-2. Service Area Data

Data Field	Description
Service Area Name	Enter the name of the Service Area
Meters at Connection (yes/no)	Check **YES** if present
Total Connections	Enter number
Industrial Customers (number)	Enter number
Commercial Customers (number)	Enter number
Residential Customers (number)	Enter number
Industrial Usage	Percent of total usage
Commercial Usage	Percent of total usage
Residential Usage	Percent of total usage

Data Field	Description
Per Capita Usage	Gallons per person per day
Percent Water Loss	Percent of total production
Percent Population Served	Percent of total service area population
Water Quality Records?	Check if water quality records are available
Service Area Municipality	Pick municipality name from pick list
Service Area Department	Pick department name from pick list
Data Source	Select data source. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.

2.4.3.3 Wells. To add a new well to a service area:

Click on the desired **SERVICE AREA** and right-click the mouse. A pop-up menu will appear.

Select **ADD WELL TO SERVICE AREA**. A blank entry form will appear. Enter the new well name and it will be added.

Click on the desired data field and enter the desired information. Click on the **UPDATE** button to save. The new well will be added to the database.

2.4.3.4 General Information. Clicking on a **SERVICE AREA** opens up two additional branches: **WELLS** and **STORAGE TANKS**. Clicking on **WELLS** will expand that branch to show all the wells associated with the service area. Clicking on an individual **WELL** opens the general information form for the well.

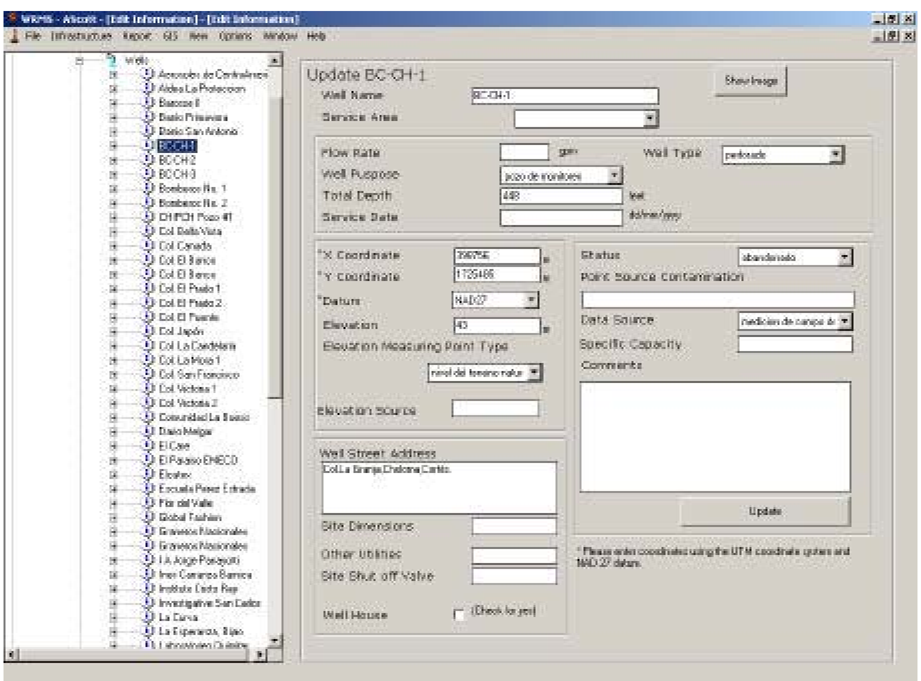

Figure 2-8. Well General Information

The table below describes the data fields available in the **WELL GENERAL INFORMATION** screen.

Table 2-3. Well General Information Data Fields

Data Field	Description
Well Name	Name of the well
Assign a New Service Area	Use the pick list to assign the well to a new service area
Flow Rate	Enter the flow rate in gallons per minute
Well Purpose	Select the purpose of the well from the list
Total Depth	Enter the total well depth in feet
Service Date	Enter the date the well went into service
Well Type	Select the type of well from the list. . If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.
Easting	Enter the easting coordinate in UTM meters, NAD27
Northing	Enter the northing coordinate in UTM meters, NAD 27
Datum	Select the datum used. If not known select unknown.
Elevation	Enter the well elevation in meters
Elevation Measuring Point Type	Select the type from the list
Elevation Source	Enter source (GPS, survey, map coordinates, etc.)
Well Street Address	Enter address, if known
Site Dimensions	Enter dimensions of site
Other Utilities	Enter other utilities present on site
Site Shut off valve	If present, describe location
Well House	Check if present
Status	Select current status of well from list
Point Source Contamination	List any potential contamination sources present
Data Source	Select data source of this information
Specific Capacity	Enter specific capacity of the well
Comments	Any additional information can go here.

Once data edits are complete, click on the **UPDATE** button to save changes.

Note: Coordinate must be entered in UTM meters using the NAD27 datum in order for the location to be properly placed on the GIS map. The user has the option of storing the coordinates using other datum, but these will not show up properly on the GIS map. It is important that these data be recorded accurately and correctly to avoid confusion about their physical location when display with other data.

2.4.3.5 Adding Images. Images and other electronic files, such as .jpg files of well completion diagrams, boring logs, spreadsheets of technical data, and site photographs can be loaded into the database for each well. To load a new image:

1. Click on the **SHOW IMAGES** button. This will open a pop-up window.
2. Click on **ADD**. A file navigation window will appear.

3. Navigate to the desired image or file.
4. Click on the image file and click the **SAVE** button.

If images are already present, they will be shown in the list. Double-click on an image to view it.

2.4.3.6 <u>Construction.</u> Clicking on an individual **WELL** opens these additional options:

- **CONSTRUCTION** – View/edit the well construction details
- **OPERATIONS** – View/edit the well operation details
- **SAMPLES** – View/edit the water quality samples for the well
- **WATER LEVELS** – View/edit the water level data for the well

An empty well construction record is automatically created when a new well is created. To update a construction record for a well:

1. Click on the desired **WELL** so that the **GENERAL INFORMATION** screen is showing,
2. Click **ON WELL CONSTRUCTION** in **THE DATA TREE**. The well construction data screen will appear.

Enter the desired construction data and click the **UPDATE** button. Construction details will be added for the well.

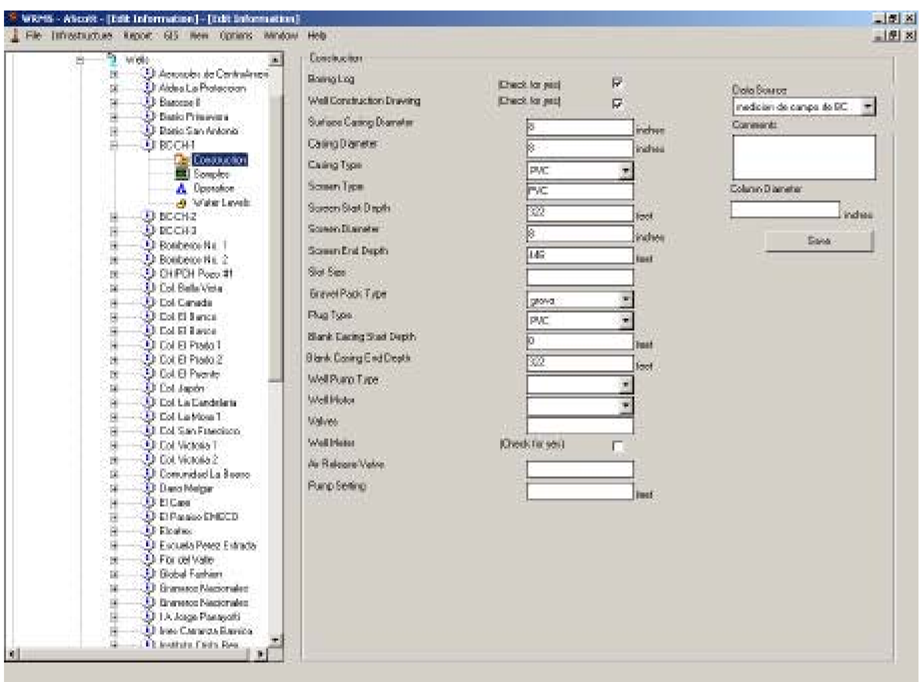

Figure 2-9. Well Construction Details Screen

The table below describes the data fields available in the **WELL CONSTRUCTION** screen.

Table 2-4. Well Construction Data Fields

Data Field	**Description**
Boring Log	Check (**YES**) if a boring log is available.
Well Construction Drawing	Check (**YES**) if a well construction drawing is available
Surface Casing Diameter	Enter the surface casing diameter if different from the casing diameter, in inches
Casing Diameter	Enter the casing diameter for the well, in inches
Screen Diameter	Enter the screen diameter for the well, in inches
Casing Type	Pick the casing type from the list. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.
Screen Type	Pick the screen type from the list
Screen Start Depth	Enter the start depth, in feet from the ground surface, for the first screen
Screen End Depth	Enter the end depth, in feet from the ground surface, for the last screen
Slot Size	Enter the slot size for the screen
Gravel Pack Type	Pick the gravel pack type from the list
Plug Type	Pick the plug type from the list
Start Casing Depth	Enter the start depth, in feet from the ground surface, for the beginning of the casing
End Casing Depth	Enter the end depth, in feet from the ground surface, for the end of the casing.
Well Pump Type	Pick the type of well pump from the list
Motor	Enter the rating of the motor, in horsepower (hp)
Valves	Enter the types of valves present
Well Meter	Check if the well flow is metered
Air Release Valve	If an air release valve is present, describe
Pump Setting	Enter the depth of the pump setting from the ground surface, in feet
Data Source	Pick the data source for the construction information from the list
Comments	Enter any comments about the well construction
Column Diameter	Enter the column diameter in inches

2.4.3.7 Operation. When a new well is created, an operation record is automatically created for it. To update the data for a well:

1. Click on the desired **WELL** so that the **GENERAL INFORMATION** screen is showing,
2. Click on **OPERATION** in the **DATA TREE**. The well operation data screen will appear.

Enter the desired construction data and click the **UPDATE** button. Operational information will be added for the well.

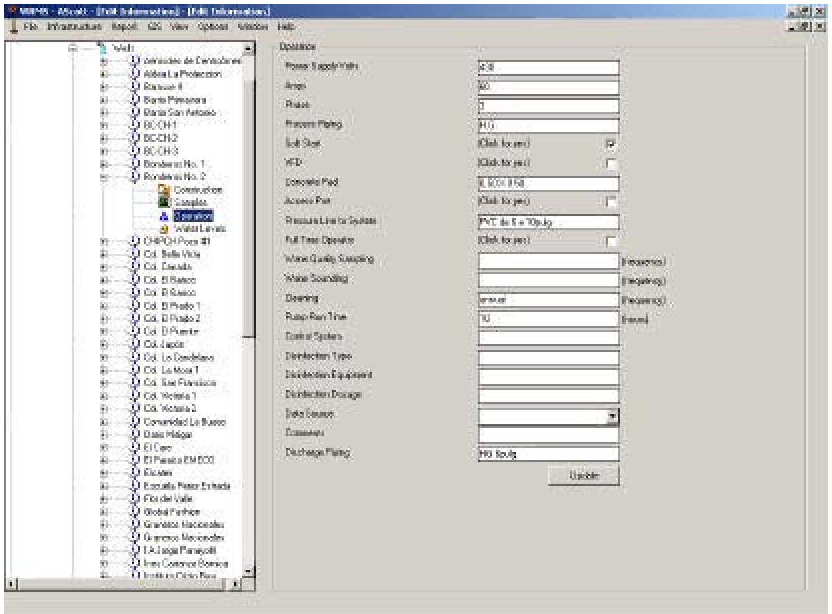

Figure 2-10. Well Operation Data Screen

The table below describes the data fields available in the **WELL OPERATION** screen.

Table 2-5. Well Operation Data Fields

Data Field	Description
Power Supply Volts	Enter the voltage of the power supply
Amps	Enter the amperage of the power supply
Phase	Enter the number of phases for the power supply
Soft Start	Check if a soft start device is present
VFD	Check in a variable flow device is present
Concrete Pad	Describe the concrete pad
Access Port	Check if an access port is present
Pressure Line to System	Describe the line to the system
Full-time Operator (yes/no)	Check (**YES**) if there is a full-time operator at the well
Frequency of Water Quality Sampling	Enter the frequency of water quality sampling (e.g. monthly, semi-annually, etc)
Frequency of Water Sounding	Enter the frequency of water level measurements
Frequency of Cleaning	Enter the frequency of cleaning
Pump Run Time	Enter the number of hours a day the pump is set to run
Control System	Describe the control system, if any
Disinfection (yes/no)	Check (**YES**) if there are any disinfection practices
Disinfection Type	Pick the type of disinfection from the list. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.

Data Field	Description
Disinfection Equipment	Describe disinfection equipment
Disinfection Dosage	Enter the amount, including units (e.g. 10 mg/l)
Data Source	Pick the data source for the construction information from the list
Comments	Enter any additional operation comments
Discharge Piping	Describe the discharge piping

2.4.3.8 Water Quality. Water quality sample results can be stored and viewed for each well. The data are organized by sampling event. Each sampling event must be entered into the system in order to record the resulting water quality. Three types of information are needed to enter water quality information:

- **CHAIN-OF-CUSTODY (COC)** – Information about the form used to describe the sample for the analyzing laboratory.
- **SAMPLE** – The type of sample taken. A COC can contain more than one sample. Multiple samples can be entered for one COC.
- **RESULTS** – The analytical results from the tests performed at the laboratory. Each sample will have one or more test results.

Please see the Sample Manual Reference for more details on water quality sampling procedures.

To enter new water quality sampling results, navigate to the desired well in the **DATA TREE** and click the '+' to open well options. Click on the **SAMPLES** option. An empty grid will be shown on the right like the one below.

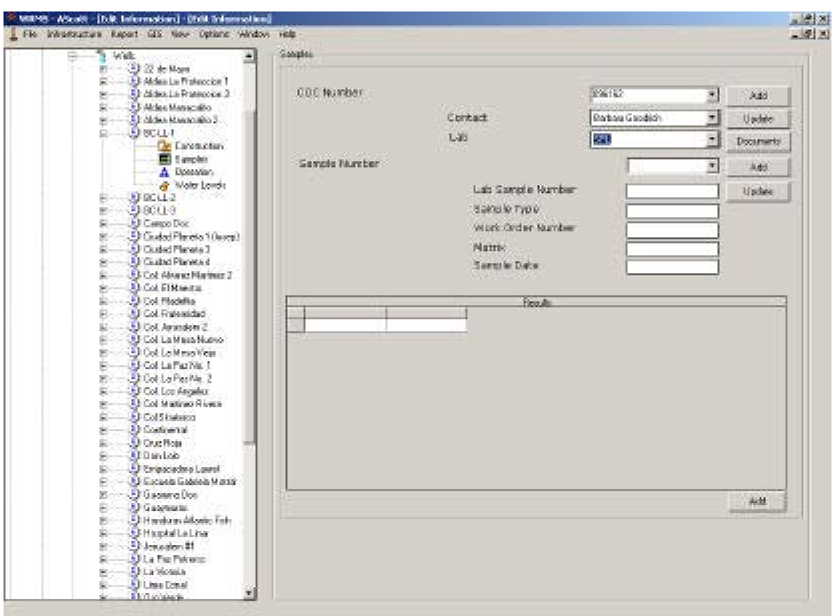

Figure 2-11. Initial Form for Water Quality Samples

Start by entering a new chain-of-custody number. Click on the upper-most **ADD** button. A popup form will appear prompting the user to enter the COC number, sampler, and analytical laboratory. Enter the data and click the **UPDATE** button.

Note: As a best practice, a unique COC number should be present on every chain of custody in order to accurately track and identify the samples when communicating with the laboratory or identify the sample results. A COC number must be entered for each sampling event. If no number is available, create a number that will be unique within the database. A good system, for example, would be to use the following pattern:

UNK-{Well Name}-{DDMMYY}

For well LC1 sampled on October 28, 2001 the COC number would be:

UNK-LC1-281001

By concatenating the well name and the sample date, a unique identifier can be created.

Descriptions of all the COC fields are shown in the table below:

Table 2-6. Chain-of-Custody Data Fields

Data Field	**Description**
COC Number	Unique chain-of-custody number. See Note describing required COC numbering
Contact	Pick the name of the person in responsible for the sampling. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.
Laboratory Name	Pick the name of the laboratory responsible for the analysis.

Once the COC is created a sample number must be entered. This sample number is the number for the sample identified on the COC. To enter a new sample, click on the second **ADD** button. A popup screen will appear prompting the user for sampling information.

When adding a new sample, make sure that the correct COC is selected. The sample number, sample name, laboratory sample number (enter UNKNOWN if not available) and sample date are required fields. The following table shows the sample data fields.

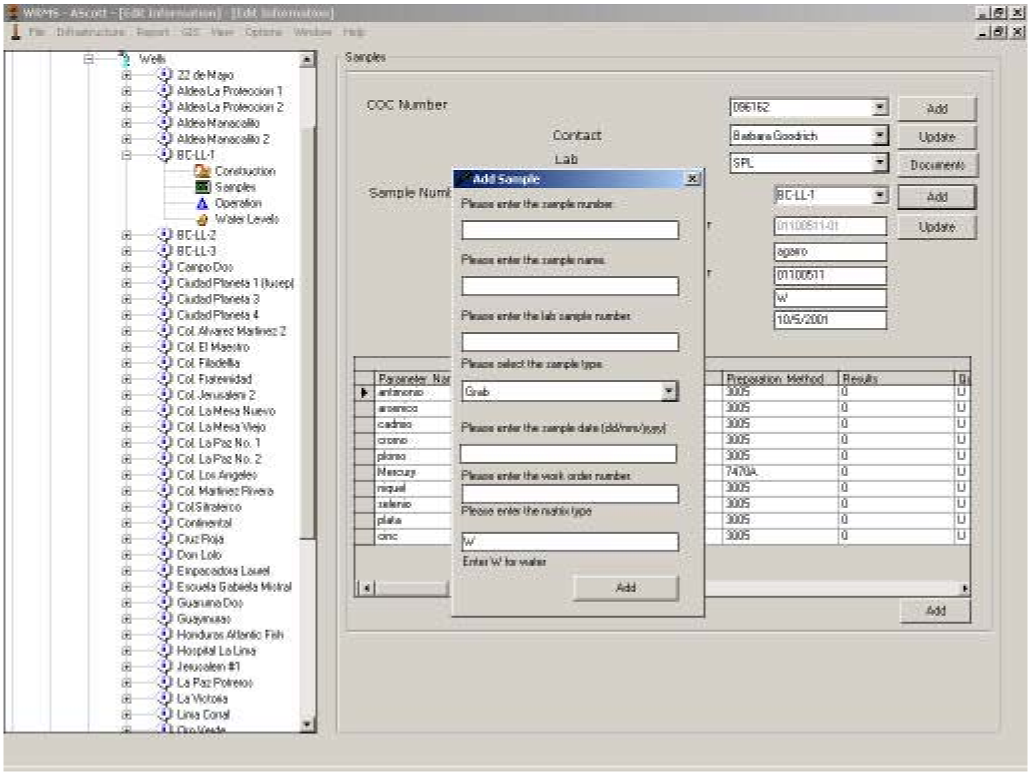

Figure 2-12. Sample Data Entry Screen

Table 2-7. Sample Information Data Fields

Data Field	Description
Sample Number	Designated sample number. This field is required
Sample Name	Name of sample, if used.
Laboratory Sample Number	Sample number designated by the laboratory. Enter UNKNOWN if not available.
Sample Type	Pick the sample type from the list. Grab sample is the most common type
Sample Date	Date sample was taken
Work Order Number	Number of the work order, if used
Matrix	Matrix of the sample. W, or Water, is most common

Once the sample is entered, analytical results can now be entered into the system. To start adding results click the third **ADD** button. A pop-up screen for sample results will be displayed.

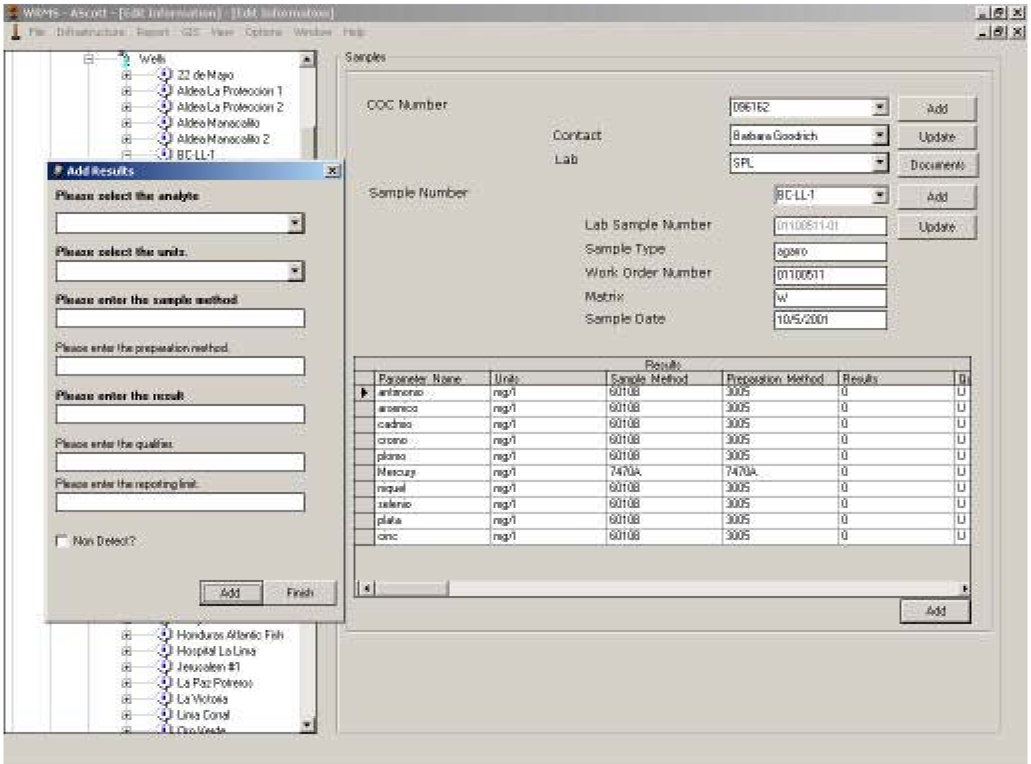

Figure 2-13. Analytical Results Data Entry Screen

The following table shows the results data fields.

Data Field	Description
Analyte Name	Pick the analyte name from the list
Units	Pick the analysis units from the list
Sample Method	Pick the analysis method from the list
Preparation Method	Pick the preparation method from the list, if known
Result	Enter the result. If it is a non-detect, enter 0, and check (YES) the ND checkbox. Otherwise, enter the value. See note below.
Qualifier	Enter any data qualifiers identified by the laboratory
Method Reporting Limit	Enter the reporting limit if known. Required for non-detects.
ND Flag	Check (YES) if the result is a non-detect.

Note: Typically a laboratory will report a non-detect as 'less than a specified reporting limit' as the result. For example, if a result of '< 5 mg/l' is reported by the laboratory, where '<' indicates that the nothing was detected and '5 mg/l' is the reporting or detection limit tested against. To report non-detects in the database:

- *Enter a zero (0) in the* **RESULTS** *field.*
- *Check (***YES***) the* **ND CHECKBOX**
- *Enter the reporting limit in the* **METHOD REPORTING LIMIT** *field.*

This procedure must be followed in order for the reports to properly format non-detect results.

To view water quality results for a well, navigate to the well in the **DATA TREE**, expand the options for the well, and click on **WATER QUALITY**. Select the desired **COC** and **SAMPLE** from the pick list. The analytical results will be displayed in the grid below.

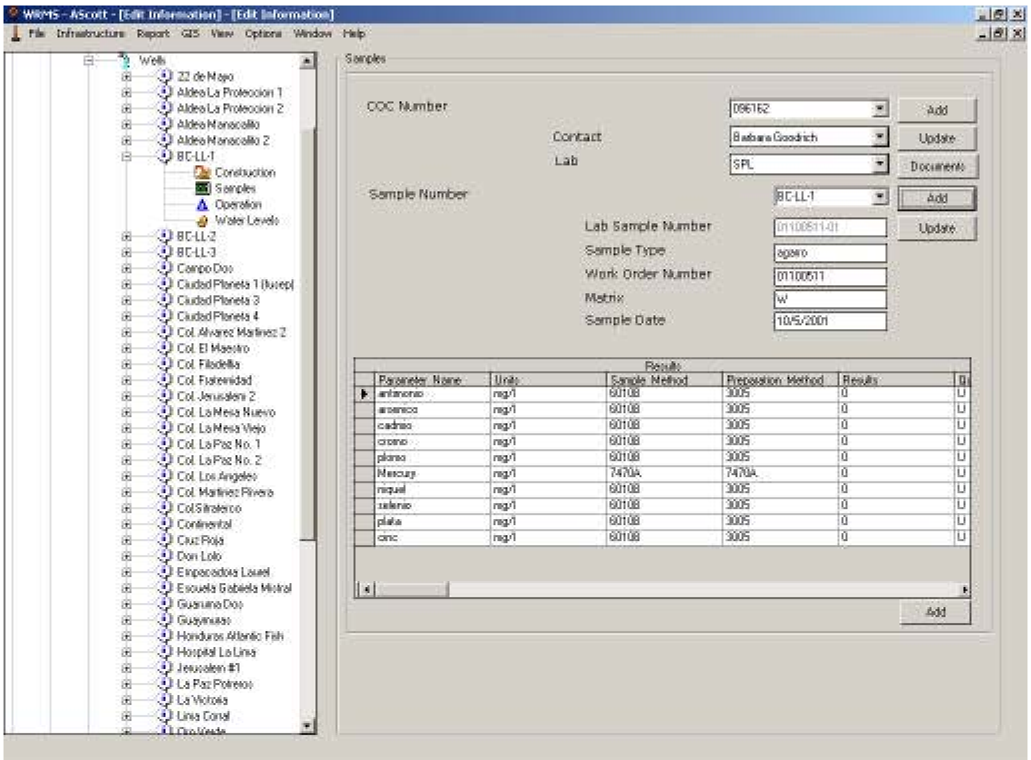

Figure 2-14. Analytical Results Table

To view an analytical summary for the well, go to the **REPORT** menu and select the **HITS REPORT**. See the Creating Reports section below for further details.

2.4.3.9 <u>Water Levels.</u> Water level measurements can be stored for each well by clicking on the **WATER LEVELS** option under the desired well in the **DATA TREE**. This will open a table of water levels for the well. To add one, click on the **ADD** button. A pop-up window will appear, prompting for entry of a new water level measurement. Enter the data and click on the **OK** button to save the entry. The following table shows the data elements associated with water levels.

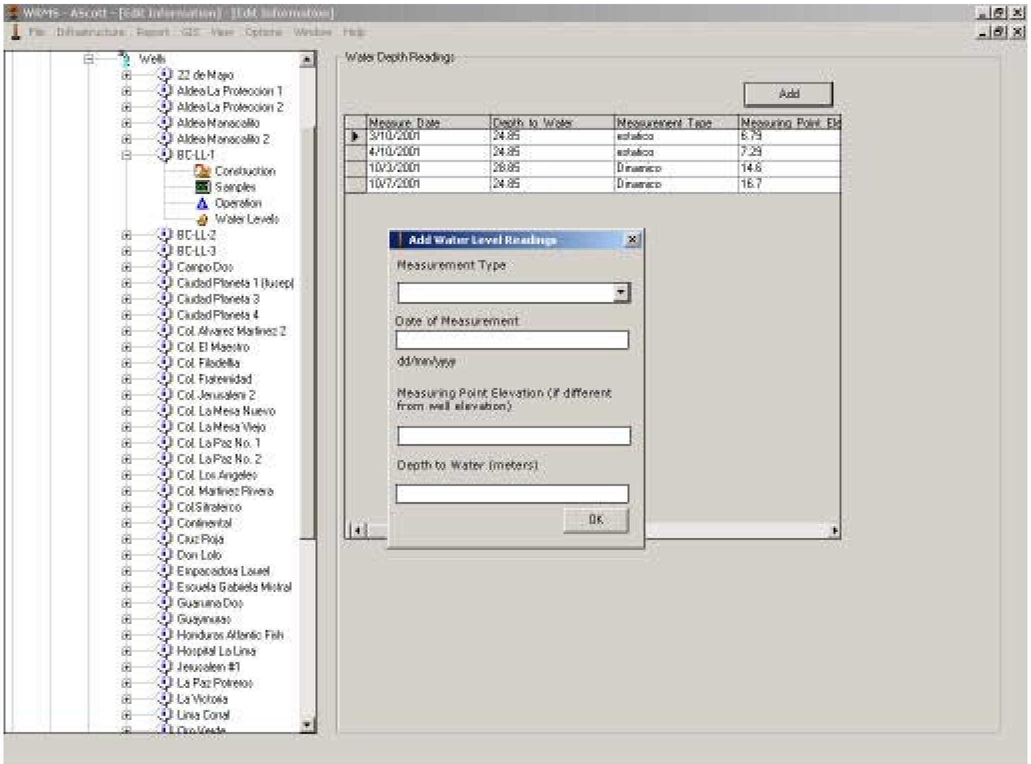

Figure 2-15. Water Level Measurement Data Entry Form

Data Field	Description
Measure Date	Enter the date the measurement was taken (DD/MM/YYYY)
Water Level	Enter the depth to water, in meters
Measurement Type	Pick the type of measurement (e.g. static or dynamic)
Measuring Point Elevation	Enter the elevation of the measuring point, in feet, if different from the well elevation. This is important in order to accurately identify the water table elevation at the well.

2.4.3.10 Storage Tanks. Storage tanks within a service area are also stored in the WRMS. To navigate to storage tanks, expand the **STORAGE TANKS** branch of a particular service area.

To enter a new storage tank, click on the **SERVICE AREA** and right-click the mouse. A popup menu will appear. Select **ENTER STORAGE TANK**. A blank storage tank form will appear, prompting for the name of the new storage tank. Enter the name and click **OK**. A new storage tank will be entered into the database.

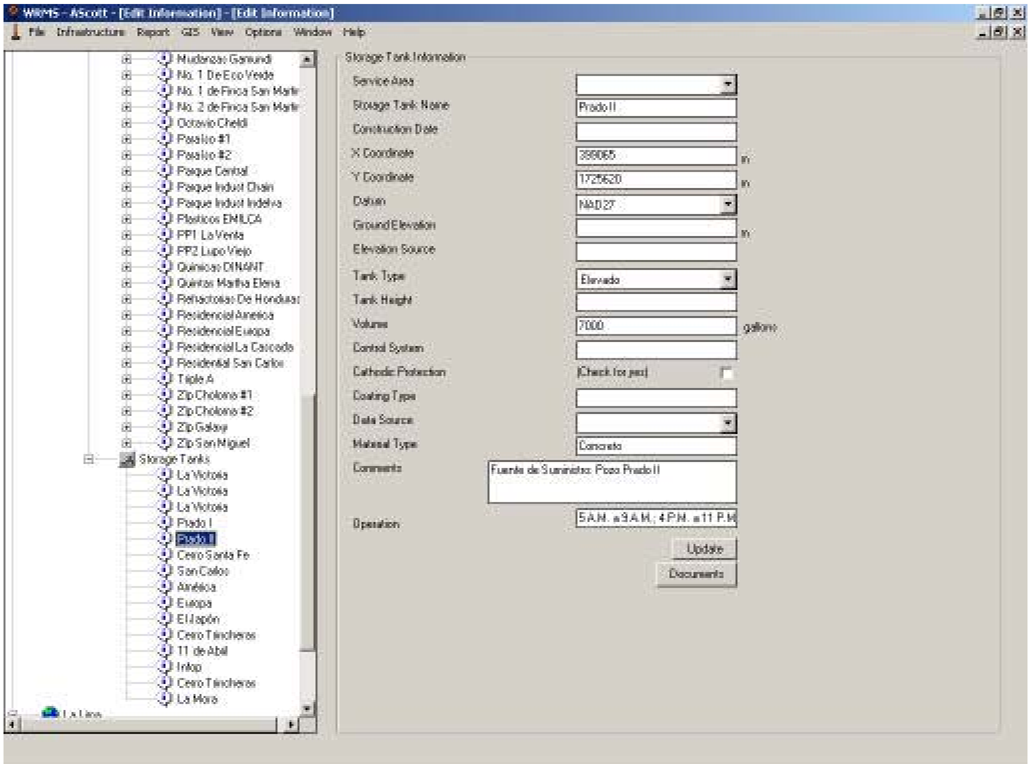

Figure 2-16. Storage Tank Data Entry Screen

The following table shows the data elements for storage tanks:

Data Field	Description
Service Area	Pick a service area from the list to change the designated service area
Storage Tank Name	Enter the name of the storage tank
Construction Date	Enter the construction date
Easting	Enter the Easting Coordinate in UTM meters., NAD27 Datum.
Northing	Enter the Northing Coordinate in UTM meters, NAD27 Datum.
Datum	Enter the Datum (e.g. NAD 27, WGS 84)
Elevation	Enter the elevation in meters
Elevation Source	Enter the source of elevation data (GPS, survey, map coordinates, etc)
Tank Type	Pick the type of tank from the list
Tank Height	Enter the height of the tank in meters
Volume	Enter the volume of the tank in gallons
Control System	Describe the Control System, if any
Cathodic Protection	Check (YES) if cathodic protection is available
Coating Type	Pick the type of coating from the list
Material Type	Pick the type of material from the list
Operation	Enter the hours of operation or enter continuous if operated 24 hours a day
Comments	Enter other descriptive information here

Data Field	Description
Data Source	Pick the source of the data. If selection is not available, it may be entered into the pick list. See the Administrators Guide for details on adding valid values.

Note: Coordinate must be entered in UTM meters using the NAD27 datum in order for the location to be properly placed on the GIS map. The user has the option of storing the coordinates using other datum, but these will not show up properly on the GIS map. It is important that these data be recorded accurately and correctly to avoid confusion about their physical location when display with other data.

2.4.4 Creating Reports. The WRMS allows the user to create standard reports from information in the database. These reports are tabular or graphical output that can be viewed on screen or printed to a standard printer.

The following reports are available:

- **HITS REPORT** – Lists all the positive analytical results for a selected well.
- **ANALYTE TREND** – Presents a linear graph showing concentration over time for a selected analyte for a well.
- **WELL CONSTRUCTION** – Print out well construction specifications for a set of wells.
- **WELL EQUIPMENT** – Lists equipment installed on selected wells.
- **WELL OPERATIONS** – Presents operational, maintenance, and cleaning information for wells.
- **STORAGE TANKS** – Lists storage tank specifications.
- **MUNICIPAL GROWTH** – Shows historical and projected growth and consumption information for municipalities.
- **SERVICE AREA STATISTICS** – Lists water consumption and use information for a service area.

Each report will be created using a similar process. To create a report:

1. Click on **REPORTS** on the main menu. The reports submenu will open up.
2. Click on the desired report from the submenu.
3. Once a report is selected, a series of popup windows will open prompting the user to make selections. For example, the **ANALYTE TREND REPORT** prompts the user to select one or more wells and then one or more analytes to display.
4. When selection is complete, the report will be generated for the wells identified.

2.4.5 Map Analysis. The WRMS can be used to create customized maps of water resource data. This is done using ESRI's ArcView® software. ArcView® is a geographic information system (GIS) used to view, analyze, and print customized maps and data.

ArcView® is integrated into the WRMS so that the user can launch a customized project from the WRMS user interface. This will open ArcView® showing all available GIS data for the municipality. The user will then turn on or off specific layers, change the map extent, interactively query the database for wells or storage tanks, and print out maps on a standard printer.

In order to the most flexibility and to leverage the existing capability of the ArcView® software, the standard ArcView® user interface has been used with minor enhancements. This users guide will present a brief overview of the inherent capabilities of ArcView®. For a detailed discussion using ArcView®, please see 'USING ARCVIEW GIS' users guide that comes with ArcView® or access the on-line help by clicking on **HELP; HELP TOPICS** from the menu bar.

The ArcView® system draws data from the WRMS database. For example, the coordinates for wells and storage tanks are derived directly from the database. Other information can be queried or viewed on the maps as well.

To open ArcView® from the WRMS, click on **GIS** from the main menu. A submenu will appear. Click on **BASE MAP**. This will open ArcView® and show all available data.

The figure below shows the main components of the ArcView® interface:

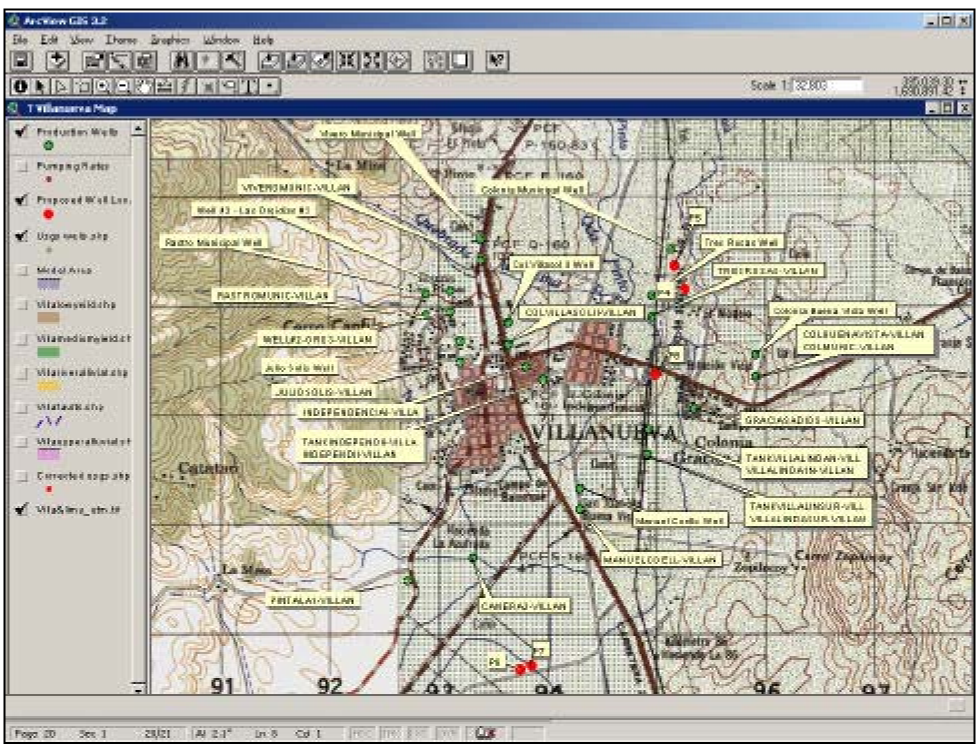

Figure 2-17. ArcView® Interface

The **MENU BAR**, **BUTTON BAR**, and **TOOL BAR** contain functions and controls for manipulating the map information, which is displayed in the map display area. The **LEGEND** is used to turn on and off data layers, and to change colors or symbols. The **MAP DISPLAY AREA** is where the map's elements are displayed.

Below, some of the most common ArcView® functionality is described, to enable the user to perform basic operations. Detailed description of ArcView® is beyond the scope of this document.

2.4.5.1 Close the ArcView® Interface. ArcView® is opened automatically when **BASE MAP** is selected from the **GIS** option on the WRMS main menu. This will open a separate ArcView® session every time the menu choice is selected. ArcView® and the WRMS window can both be open and operational simultaneously. To close the ArcView® session, select **FILE; EXIT** from the ArcView® Menu Bar. Alternatively, click on the 'X' in the upper right corner of the window. The user may be prompted to save changes before exiting. Saving changes will enable ArcView® to open to the same settings that were in place when the session was closed. Otherwise, ArcView® reverts to the previously saved settings.

2.4.5.2 Save Changes. The user can save changes made during the ArcView® session at any time. Either click on the **SAVE** button on the tool bar, or select **FILE; SAVE PROJECT** from the menu bar

2.4.5.3 Turn On or Off Layers. Each map layer that can be displayed is shown in the legend on the left side of the screen. Turn on each layer by clicking on the checkbox to check it. The map display area will be redrawn with the new layer shown. Uncheck the box to turn off the layer.

Each map layer (called a 'Theme' in ArcView®) corresponds to a source data file, called a Shapefile. Shapefiles each have an extension (file suffix) of 'shp' and are stored as regular files on the computer system. The shapefile contains the graphics and attribute data necessary to select and display information in the map display area. Please see the 'USING ARCVIEW GIS' users guide or access the on-line help (by clicking on **HELP; HELP TOPICS** from the menu bar) for more information on manipulating and adding shapefiles.

2.4.5.4 Change Symbol. The symbols for each of the map layers can also be changed. To do so, click on the layer so that it is highlighted by a box, then click on the **EDIT LEDGEND** button on the tool bar. This will open the legend editor pop-up window. Double click on the symbol (put the pointer on the symbol and click the left mouse button twice rapidly) to open the symbol window. Chose a new symbol, color, or line symbol and click the 'X' in the upper right hand corner of the symbol window. When the symbol window has closed, click on the **APPLY** button on the legend editor window to update the map with the new symbol. Close the legend editor window by clicking on the 'X' in the upper right hand corner.

2.4.5.5 Zoom In or Out. The geographical extent of the map view can be changed by zooming in or out. To zoom in (examine a smaller area in more detail), click on the **ZOOM IN** button on the tool bar. The cursor will change to a cross. Place the cursor on the new upper left-hand corner, press *and hold* the left mouse button. Drag down and to the right to define the new area for the map. When the button is released, the map will be redrawn to the new boundaries in the map display area. To return to the previous image, click on the **PREVIOUS EXTENT** button on the button bar.

To zoom out (see more area), click on the **ZOOM OUT** button on the tool bar. Place the pointer in the center of the map display area and click the mouse. The area will be enlarged by a power of two. Continue to zoom out until the appropriate display is shown.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.6 Pan. The user may want to move to a new area of the map without changing the scale of the display. This is called a pan. To pan, click on the **PAN** button on the tool bar . The pointer will turn into a hand.

Place the hand on the location on the map that will become the new center in the map display. Press *and hold* the left mouse button. Drag the location to the center of the display. The map will be dragged over to become the new center of the display.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.7 Identify Data. ArcView® allows the user to explore associated data for any of the data layers shown. To do so, click on the desired data layer in the **LEGEND** so that it is highlighted with a box. Then, click on the **IDENTIFY** button on the tool bar . The pointer will become an 'i' with cross-hairs. Put the pointer over the desired feature and click the mouse. A popup window will appear showing related data for the feature selected.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.8 Measure Length. To measure the distance between map features, click on the **MEASURE** button on the tool bar . The pointer will turn into a ruler. Click on a point to begin measurement. Click as many times as needed to define the line (the measurement does not have to be a straight line). The segment length and total length will be shown on the status bar on the bottom left-hand side of the screen. When finished double-click the last point.

To get out of zoom mode, click on the **POINTER** on the tool bar .

2.4.5.9 Print a Map. There are two ways to print a map. Either print the current view or create a layout for printing. Printing the current view is a quick way to produce a paper copy. Using a layout allows the user to produce a more formal map.

To print the current view, click on **FILE; PRINT** from the menu bar. A printer popup window will appear. Click **OK** to print

To create a default layout for printing, click on **VIEW; LAYOUT** from the menu bar. This will open the **LAYOUT MANAGER** popup window. Select the **LAYOUT TEMPLATE** and click **OK**. Select a new layout and click **OK**. A new layout will be created for printing. To print the layout, make sure the layout window is the active window (click on the layout once to make sure). Then print using the **FILE; PRINT** menu selection from the menu bar.

Close the layout by clicking the 'X' in the upper right-hand corner of the window.

For a detailed discussion on customizing layouts, please see 'USING ARCVIEW GIS' users guide that comes with ArcView® or access the on-line help by clicking on **HELP; HELP TOPICS** from the menu bar.

2.4.5.10 Well Classification. Well data can be displayed in the current view. The wells will be color coded by the type of data selected. The types of data that can be displayed for wells are:

- **TOTAL DEPTH** – Plots the wells by total well depth (in feet),
- **STATUS** – Plots the wells by their status (e.g. active, abandoned),
- **WELL TYPE** – Plots the wells by their construction type (e.g. bored, hand dug),
- **WATER LEVEL** – Plots the wells by their water level elevation,
- **WQ PARAMETER** – Plots the wells by the concentration of a selected analyte.

To plot well classifications, do the following:

1. Select **WELL ANALYSIS** from the menu bar. This will open a sub-menu.
2. Select **WELL CLASSIFICATION** from the submenu. A pop-up window will appear.
3. Select the desired well classification. Once selected, the well symbols will be color coded by the type of classification selected.
4. (For **WQ PARAMETER** only**)** An additional menu will appear listing the analytes that can be plotted. Select the desired analyte.
5. (For **WQ PARAMETER** only**)** Once an analyte is selected, a threshold value or reporting limit can be entered. Enter the limit or value and click ok. Wells with analytical data above the limit will be colored red.

2.4.6 Well Site Prioritization. The purpose of the well site prioritization tool is to identify and prioritize candidate locations for new wells based on a user-defined set of selection criteria. The typical process for evaluating well sites is to evaluate each site against a list of specified criteria. Each site gets a numerical score for each item in the list based on how well it meets the specification. The scores are then totaled for each site, and the site with the best score becomes the best candidate for new well facilities.

An example matrix of this prioritization approach is shown in the table below.

Criterion	Multiplier	Site 1		Site 2		Site 3		Site 4	
		Rank	Value	Rank	Value	Rank	Value	Rank	Value
Pumping Cost	1	2	2	2	2	2	2	1	1
Proximity to Existing Pipelines	1	3	3	3	3	2	2	2	2
Land Ownership	2	3	6	3	6	3	6	2	4
Groundwater Quality	3	4	12	4	12	4	12	3	9
Impacts on Existing Wells	4	1	4	1	4	1	4	0	0
Aquifer Characteristics	8	5	40	5	40	5	40	4	32
Aquifer Thickness	10	3	40	1	10	3	30	2	20
Total			**97**		**77**		**96**		**68**

The candidate sites are listed across the top of the matrix and the criteria to be scored are listed on the left. Each criterion is assigned a weighting factor shown in the multiplier column above. This multiplier enables the criterion that is most important to contribute the most to the final score, and thus have the most influence on the prioritization. Each site is assigned a rank, which is multiplied by the multiplier to get an overall value for each individual criterion. The values are then summarized to a final score for each site, which is used to determine the sites that best meet the criteria.

The well site prioritization tool performs this process on the entire region to be evaluated. Each criterion in the matrix table is represented by an ArcView® shapefile theme (Please see 'Turning on or off layers in the section above for a description of shapefiles[2]). In some cases, an item from the shapefile's attribute table will need to be identified. The tool will process each shapefile into a grid (Grids are discussed in the ArcView® 'USING SPATIAL ANALYST' users guide) is developed for the entire study area, and each cell in the grid is evaluated and scored against the criteria. The scores are then added together and the cells are categorized based on how well they meet the criterion. These categories are then displayed on the basemap. The areas with the highest total scores (green) are the best candidates for new well production, and the worst are shown in red.

2.4.6.1 Entering Criterion. The Well Site Prioritization Tool already contains an example set of pre-configured criteria for analysis and decision-making. The user may start with these and make changes to evaluate the study area. This section describes in detail the concepts and procedures involved in creating and manipulating new criteria. The last part of this section describes the user interface and how to change criterion parameters.

When entering criteria, there are three types of criteria evaluation methods used in the model. These are shown in the table below:

Table 2-8. Types of Analysis Methods Used in the Well Site Prioritization Tool

Method	Description	Example	Shapefile Type	Shapefile Item	Fields Used
Value	Areas that *EQUAL* a specific value are assigned a specific rank	Any area that falls within a municipal boundary.	Polygon	Any text item	Text Value

[2] Note: Adding and defining criteria in the Well Site Prioritization tool requires an understanding of ArcView® shapefile construction, which is beyond the scope of this manual. . For a detailed discussion, please see 'USING ARCVIEW GIS' users guide that comes with ArcView® or access the on-line help by clicking on HELP; HELP TOPICS from the menu bar.

Method	Description	Example	Shapefile Type	Shapefile Item	Fields Used
Range	If the value falls within a specific *RANGE*, it is assigned a specific rank	Aquifers greater than 150 feet thick are best; aquifers between 100 and 150 feet are good; anything less in unacceptable	Line	Any numeric item	Low Value and High Value
Buffer	Used to assign rankings based on *DISTANCE FROM* a map feature	New well sites should be within 500 meters of existing infrastructure	Line or Point	None required	Buffer, Text Value (optional)

The first step in defining criteria for the model is to complete a worksheet like the example shown below. Blank forms are located in the back of this manual. In the first column, list the criterion or theme name and the significance of the criterion by assigning a multiplier. Next, select the method to be used from the table above. Next, identify the shapefile to be used in the analysis (the type of shapefile is specified for each method in the table above). Identify an attribute item to be used in the evaluation, if required by the method. Then, identify the appropriate key word for the selected method from the description field in the table above (the *CAPITALIZED / ITALICIZED* words). Next, using as many lines as necessary, fill in the possible values and their corresponding rank. Remember, these values must be present with the exact spelling and case in the attribute field selected.

In the example, there are five criterion specified, but the user can enter as many sets of criteria required for the analysis. It is even permissible to enter multiple sets of criteria for the same type of information. For example, if there are multiple aquifers present, the user can enter a set of aquifer characteristics (e.g. specific capacity) and water quality parameters for each aquifer as separate criteria.

Table 2-9. Example Worksheet for Defining Criteria for Well Site Prioritization

Criterion/ Theme	Weight/ Multiplier	Method	Shape File Name	Item for evaluation	Key Words	Value	Rank
Municipal Boundary	9	Value	boundary.shp	ID	EQUALS		
						"IN"	10
Specific Capacity	7	Range	aquifer.shp	Value	RANGE		
						0 - 50	1
						50-100	5
						100-200	7
						200-10000	10
Infrastructure	4	Buffer	infrastructure.shp		DISTANCE FROM		
						< 500	10
						> 500	0
Water Quality	4	Value	quality.shp	Value	EQUALS		
						"EXCELLENT"	10
						"GOOD"	5
						"POOR"	0
Supply Wells	5	Range	wells.shp	Status	DISTANCE FROM		
						< 100	0
						> 100	10

Once the sheet has been completed and the multipliers and ranks have been satisfactorily assigned, the data can be input into the WRMS. To do so, click on **GIS** from the main menu and pick **WEIGHTED VALUES.** The data entry form shown below will open.

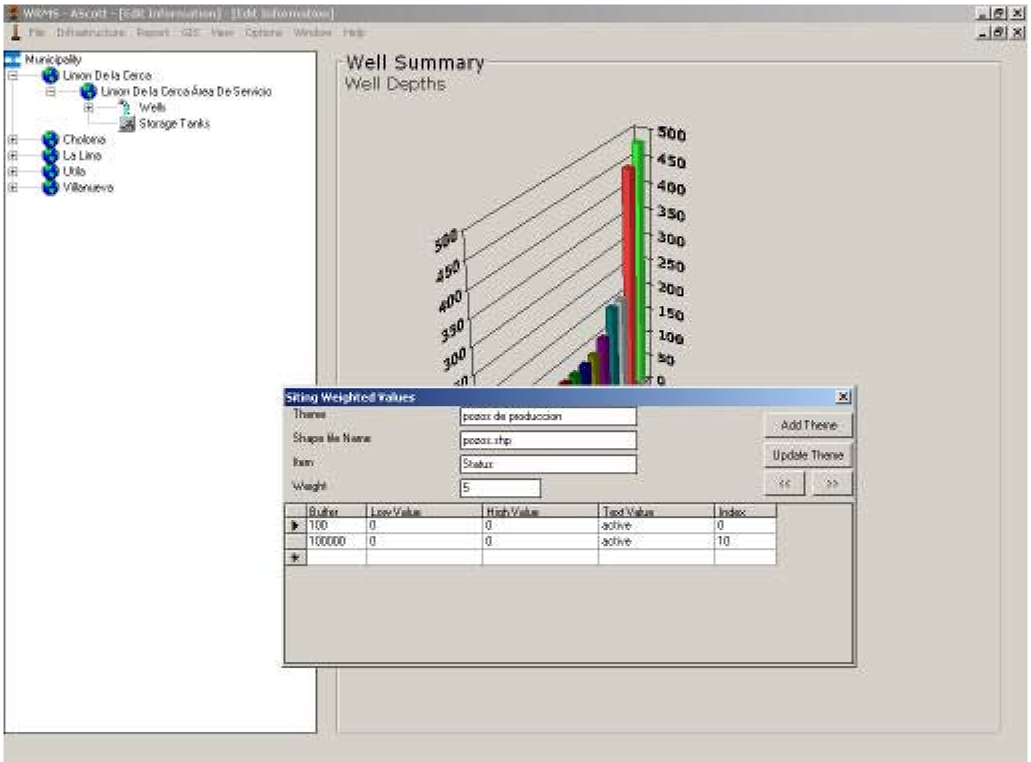

Figure 2-18. Well Siting Criterion Data Entry Screen

To enter a new criterion, do the following:

1. Click on the **ADD THEME** button. A pop-up window will appear.
2. Enter the theme name, shapefile name, field used (if any) and the weight value for the criterion.
3. Click on the **SAVE** button to store the new record.

To update a theme, enter the changes and click on the **UPDATE THEME** button.

To navigate between criteria records, click on the forward (>>) and back (<<) buttons.

1. To specify the parameters for the new criterion, click on the blank row and start entering data

Once the criteria are entered, use the same procedure to make updates and adjustments to the ranking and multiplier fields to calibrate or tune the model.

2.4.6.2 Performing the Analysis. Once the criteria are specified, the site prioritization process can be run. To start the process:

2. Click on **GIS** from the main menu and select **WELL SITE PRIORITIZATION**. An ArcView® GIS session will be initiated.
3. Select **WELL ANALYSIS** from the **MENU BAR**
4. The analysis will begin. When completed, a new layer will be added to the map display area with its corresponding scores in the legend. The values are color-coded, based on the colors shown in the legend. The higher the values, the better the match to the specified criteria.

Typical results are shown in the figure below

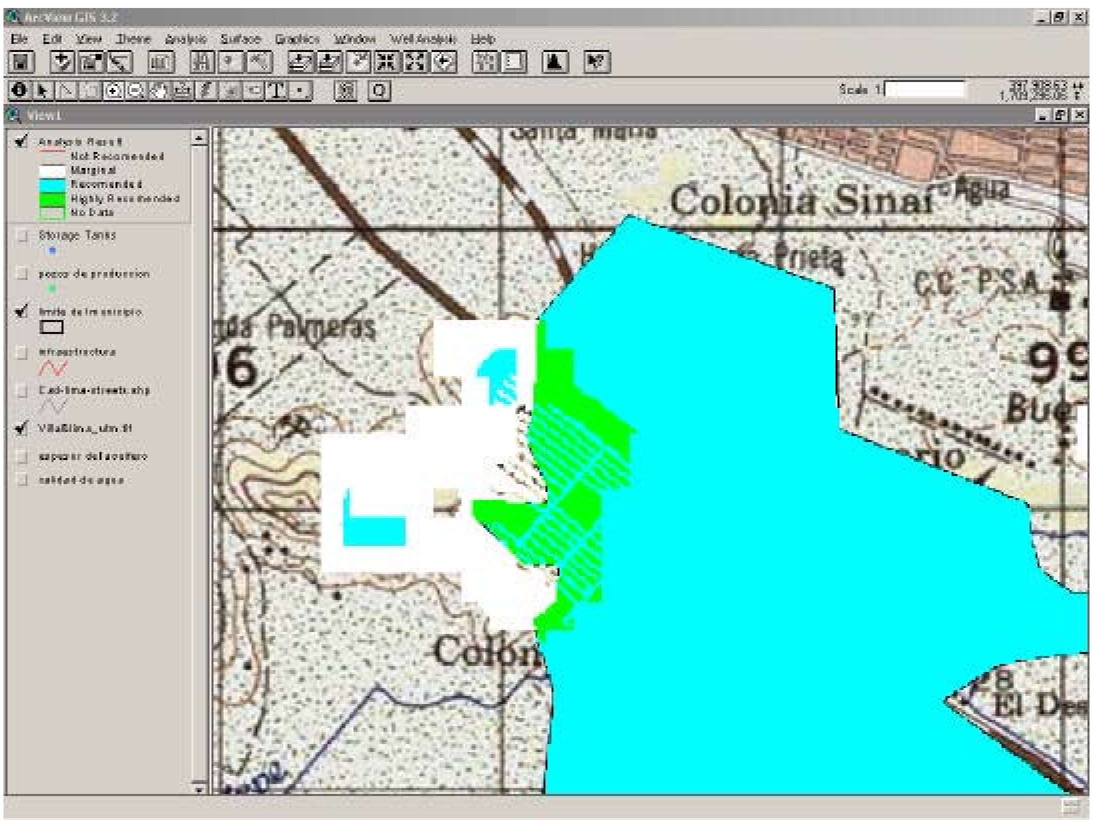

Figure 2-19. Well Site Prioritization Results

2.4.6.3 Querying the Results. The user may adjust the criteria and run the model as many times as necessary to identify reasonable ranking and multiplier values. In order to explore the results and identify the most significant contributing criteria for any location, a criteria query tool has been provided. To use the tool perform the following steps:

1. While in the ArcView® session, click on the criteria query tool button in the tool bar.

2. Locate the pointer over the location to be explored and click the mouse. A series of pop-up windows will appear displaying the criteria, the value, the weight, and total value for the point selected.

Typical results are shown in the figure below.

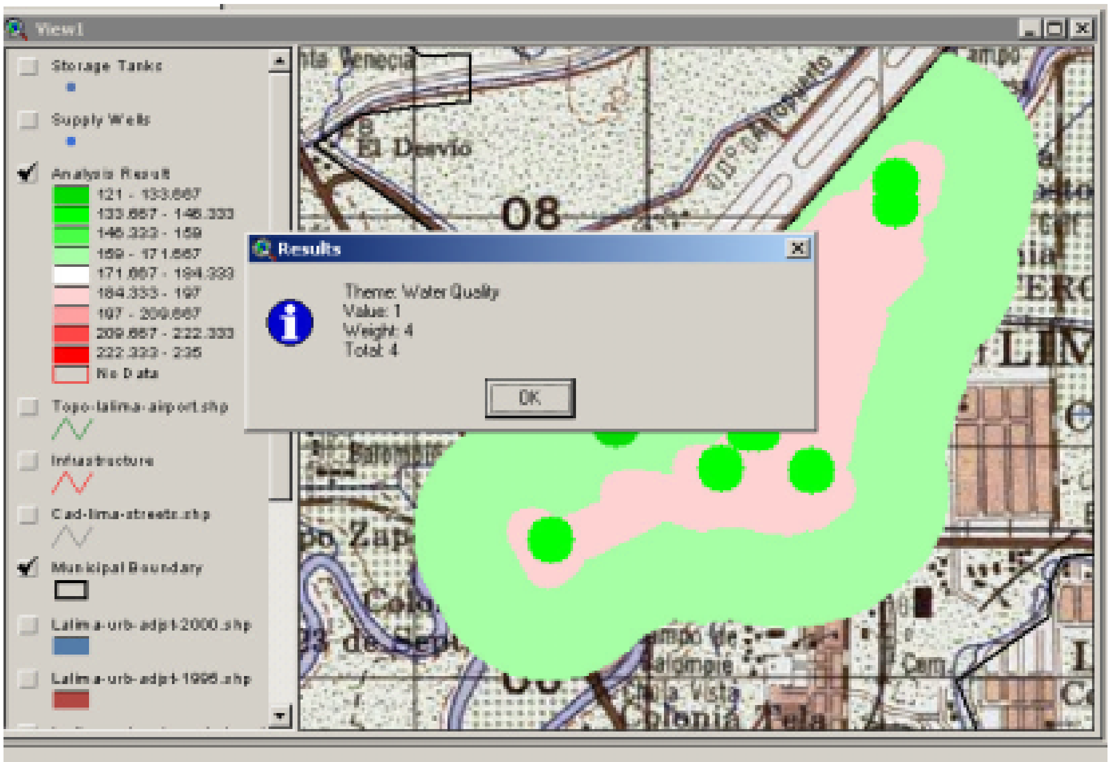

Figure 2-20. Using the Query Tool for Exploring the Siting Analysis

Using this tool, the user can evaluate the scoring characteristics for any location in the study area.

2.4.7 Assessing Related Information. The WRMS provides access to the GW Monitor – the USGS database of water supply wells – and the Water Resources Management Plan developed as part of this project. GW Monitor is an Access database that contains specifications on many of the water supply wells throughout Honduras. Many of the wells identified in WRMS are also present in GW Monitor, and it will be useful to compare the information between the two databases. To access GW Monitor, click on VIEW option from the WRMS main menu, then select USGS DATA. The GW Monitor application will open in a new window.

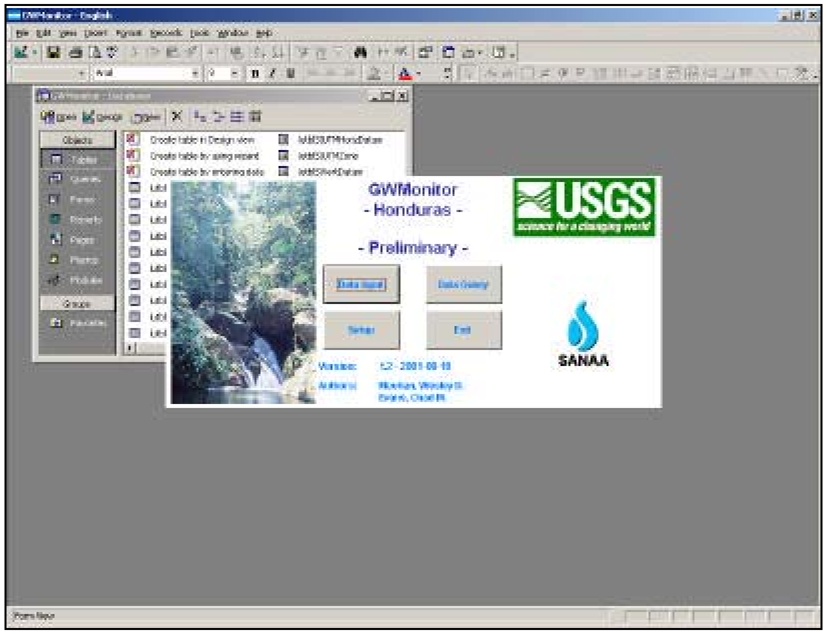

Figure 2-21. GW Monitor; the USGS Wells Database for Honduras

Once open, wells in the GW Monitor database can be queried through the functionality provided by the USGS. Please contact the USGS for information on how to use the GW Monitor database.

The Water Resources Management Plan is a report developed for each municipality containing a summary of water resource information, analysis of sustainable yield and aquifer characteristics, and recommendations for water resource management programs. The Water Resources Management Plan and WRMS are to be used in conjunction with each other. There are detailed data in the WRMS discussed and summarized in the plan, and recommendations from the plan can be explored using the WRMS. To access the Water Resources Management Plan, click on the **VIEW** button from the main menu, then select **WATER RESOURCES MANAGEMENT PLAN**. The plan will be opened in PDF format for viewing.

2.4.8 Getting Help

There are two type of user assistance available in the WRMS; assistance with the application and assistance with the ArcView® software.

2.4.8.1 WRMS Help. This users guide is available in PDF format from within the WRMS. To access help, click on **HELP** from the main menu, then select **USERS GUIDE**. The users guide will then open up in a new window. To access version information regarding the WRMS application, click on **HELP** from the main menu, then select **ABOUT**. This will open a popup screen showing the application version.

2.4.8.2 ArcView® Help. As mentioned previously, comprehensive discussions of ArcView® structure and functionality is available on-line from the ArcView® application. To access, click on **HELP** from the menu bar, then select **HELP TOPICS**. This will open a new window with help documentation.

3.0 ADMINISTRATORS GUIDE

3.1 Architecture

As mentioned previously, the data management system used in the WRMS is Microsoft Access, which is a relational database designed to efficiently manage complex data. The data are stored in a series of tables. Each table stores a different type of information, and each table is linked to others by a key field that defines the relationship. For example, one table contains a record of each well, while another table contains all the water level measurements. The table containing the water levels also contains the name of each well, so that it can be linked back to the appropriate well in the well table. This way, detailed information on each well and water level measurements can be stored most efficiently, without the need to maintain the same piece of information more than once, which would potentially introduce erroneous data into the system.

The GIS used is ArcView®, by Environmental Science Research Institute (ESRI). A GIS is an electronic mapping and analysis system. The power of GIS lies in its ability to manipulate, display, and analyze information on a map by linking map elements to attribute data in a database. For example, a well whose location is identified as a dot on the map, is connected to the construction data, sampling results, and water level information in the database. The user can post any of this information as text on the map, choose specific symbols or colors to represent these data, and overlay this layer of information on other map features. Because the data management system and GIS work together, it provides the user with a powerful set of management and analysis tools.

Both of these components are linked through a common interface developed in Microsoft Visual Basic. The interface is a series of screens that guide the user through various application functions. Through the interface the user can enter or update data, view reports, generate graphs, display scanned images, and create customized maps. The interface can be displayed in English or Spanish, uses water resource terminology, and is designed to be easy to use. Through this interface, municipalities will be able to continue to update their water resource data and use it for decision-making into the future.

3.2 Installation

The WRMS Application requires the following components to be fully installed on the system.

3.2.1 Hardware Requirements:

Minimum (Untested) configuration:

- Intel Pentium 200 MHz
- 64Mb RAM
- EIDE Drive (at least 100Mb free).

Recommended (Tested) configuration:

- Intel Pentium III 733+ MHz
- 128+Mb RAM
- EIDE RAM (at least 100Mb free)

3.2.2 Software Requirements:

The WRMS is designed to function on Microsoft Windows ME, NT4, 2000 or XP.

Additional Required Software:

- ESRI ArcView® 3.1
- ESRI Spatial Analyst
- Seagate Crystal Reports for ESRI
- Adobe Acrobat Reader (http://www.adobe.com/products/acrobat/)

3.3 Operations

This section explains how to back-up and restore the WRMS data and what to do if a system error occurs.

3.3.1 Backups and Recovery. WRMS features a basic backup and recovery system. The system allows the data stored in the system to be backed up whenever necessary. It is recommended that you set this system to backup your data at least once a week. This will enable you to recover your data if something goes wrong.

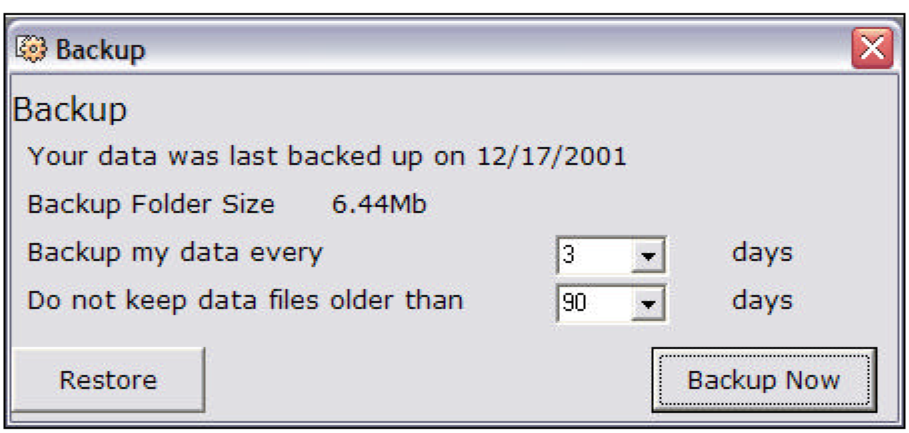

Figure 3-1. Backup and Restore Information

3.3.1.1 How to Backup Your Data. Backups are automated so there is no need to manually backup anything.

However, if you are planning on making major changes to your data or would just like to force a backup, you can force the backup by clicking the **BACKUP NOW** button.

3.3.1.2 How to Restore Your Data.

Click the **RESTORE** button on the **BACKUP** screen.

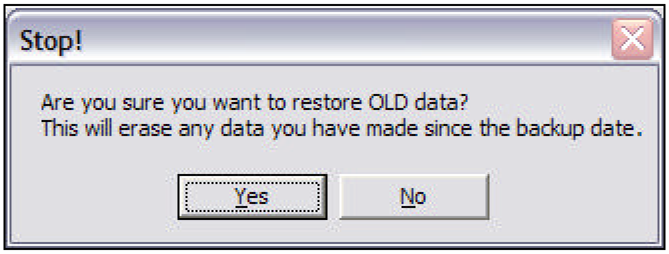

Figure 3-2. Restore Warning

Read the warning and make sure you understand the consequences of restoring OLD data.

Press **YES**.

You will then be presented by the following screen.

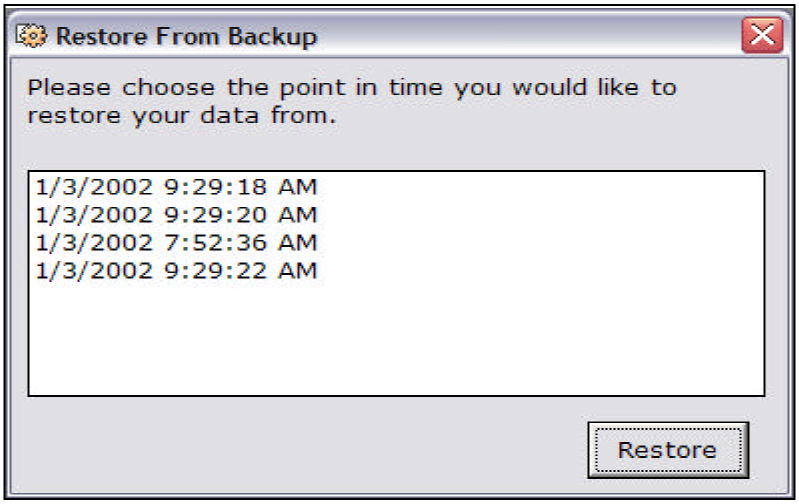

Figure 3-3. Restore from Selection of Backups

Select one of the items from the backup list. Then click **RESTORE**.

Your data will be backed up and then restored from the old data. It is recommended that you exit the application before using it again.

3.3.2 What to do if Error Occurs. We do not anticipate you encountering any errors. However, if you do encounter any errors make sure you write down the error number and what you were trying to do at the time that the error occurred. Send the details to the following email address: sac-support@brwncald.com.

3.3.3 Options

This section describes how to manage valid values, data paths, and interface translations.

3.3.3.1 Valid Values. Valid values allow you to alter and add to the contents of the drop-down menus. The illustration below shows part of the WRMS application. It includes a drop-down menu to change the well purpose of a well. The menu is populated using valid values.

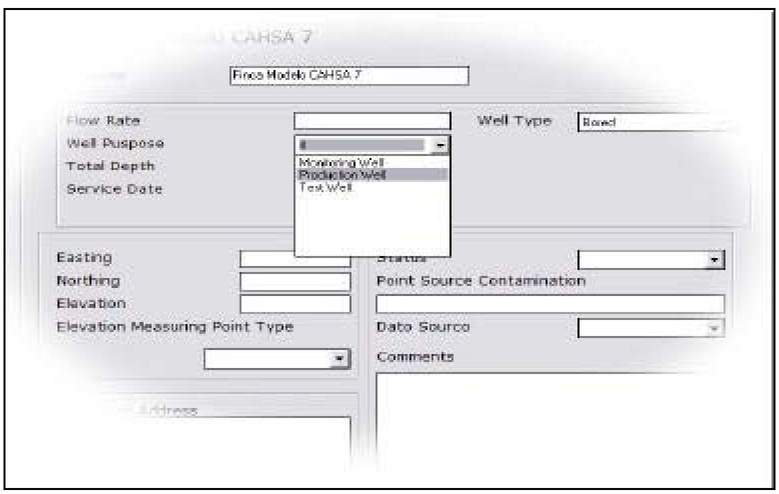

Figure 3-4. Well Purpose Drop-Down Menu Populated with Valid Values

You can easily change the valid values for this drop-down menu by pointing to **OPTIONS; VALID VALUES** then clicking on **WELL PURPOSE**.

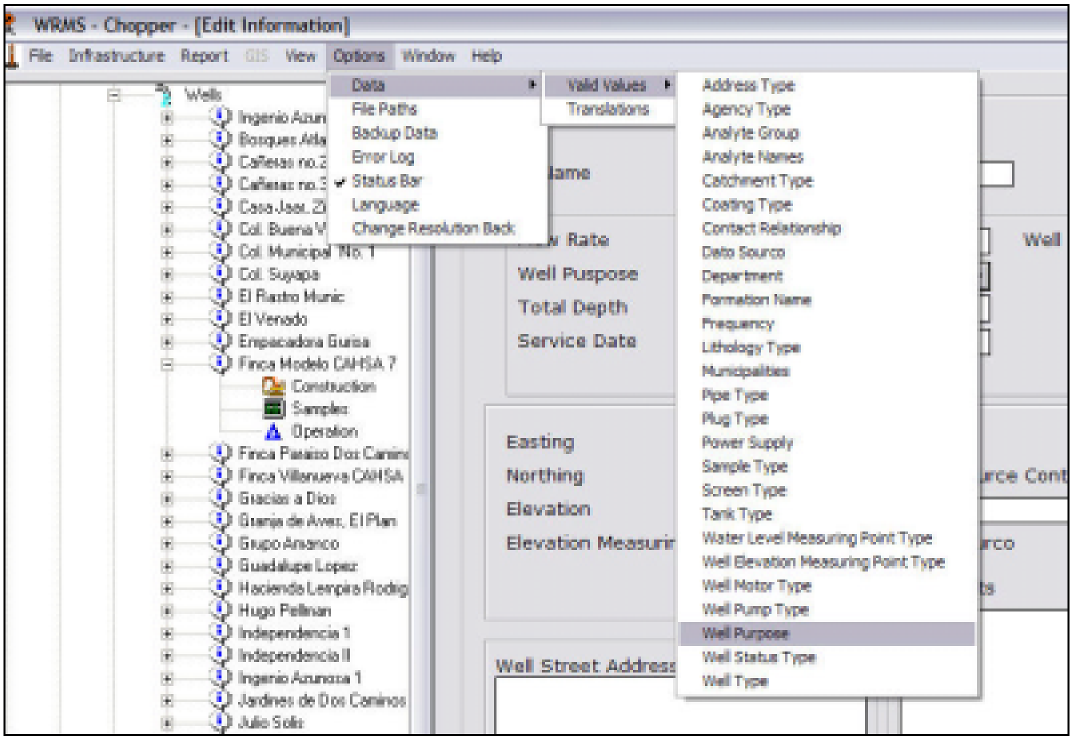

Figure 3-5. Valid Values Menu

You should follow the same process for any other drop-down menu in the application. This way the values can be easily managed.

3.3.3.2 <u>Data Paths.</u> WRMS requires some additional files to run with the full functionality. The following files should be setup in the **FILE PATHS** menu under **OPTIONS**.

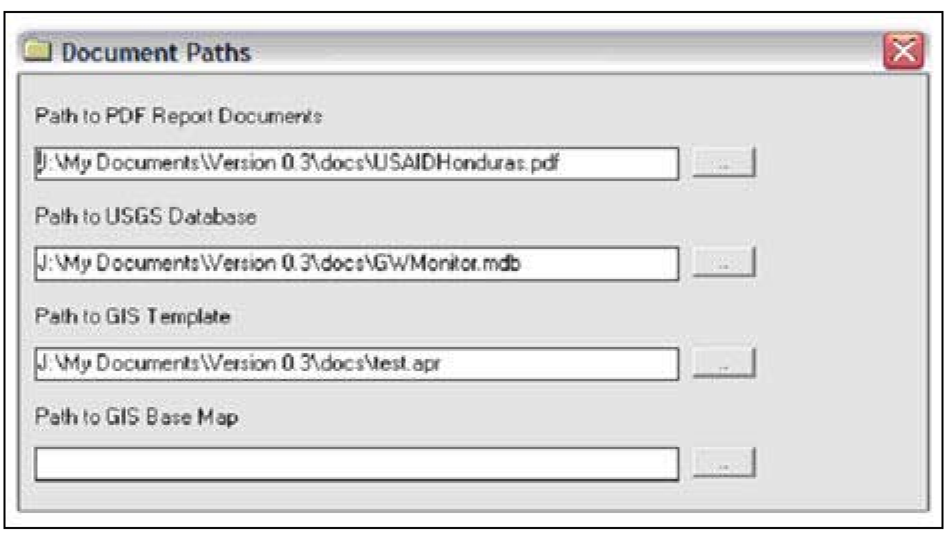

Figure 3-6. File Paths

Unless you are sure what you are doing, we strongly suggest you stay away from these options.

3.3.3.3 <u>Translations.</u> WRMS supports both English & Spanish. Because WRMS was developed in English, some of the translations may be incorrect. You may change these at any time by pointing to **OPTIONS; DATA** and then clicking on **TRANSLATIONS**. Here you will be presented with the English version of all the phrases that the application uses. You can update the Spanish by typing in the cell to the right of the English.

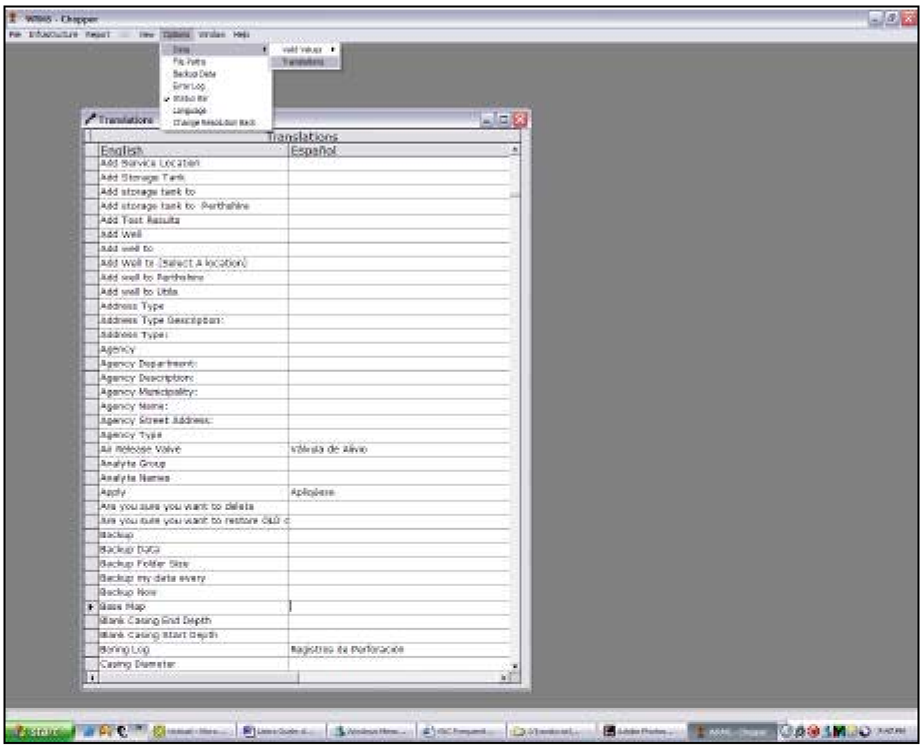

Figure 3-7. Translations Screen

ATTACHMENT

Criteria Worksheet

CRITERIA WORKSHEET

Criterion/Theme	Weight/ Multiplier	Method	Shape File Name	Item for Evaluation	Key Words	Value	Rank

Key Words: Equals
Range
Distance From

APPENDIX F

Groundwater Level and Monitoring Program
(Field Manual)

GROUNDWATER LEVEL AND MONITORING PROGRAM

FIELD MANUAL

BROWN AND CALDWELL

DECEMBER 2001

USAID

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

APPENDICES

1.0 PURPOSE AND OBJECTIVES

The purpose of this Sampling and Analysis Plan (SAP) is to outline the essential elements for establishing an effective groundwater level and monitoring program at various municipalities in Honduras, Central America. This report and guidance document is written in support of the Groundwater Monitoring Study conducted by Brown and Caldwell under USAID contract number 522-C-00-01-00287-00. This report covers the technical approach for the groundwater level and monitoring program, the rational for established procedures and step-by-step guidance for the continuation of the monitoring program into the future.

2.0 OVERVIEW

The groundwater level and monitoring program is being established to provide a tool that will be used in support of the current groundwater modeling effort. In addition, the monitoring program will provide a tool for future data collection that will be useful for growth planning.

The groundwater level and monitoring program has several components that are all equally important. These components include groundwater level data collection, water sample collection, analysis of water samples and review, compilation and understanding of water chemistry results. Each of these components is necessary in order to maintain a successful groundwater monitoring program. Each of these components is used to support and enhance the groundwater modeling effort and is discussed in more detail in later sections of this report.

3.0 TECHNICAL APPROACH

3.1 Well Selection

For this study, two types of wells were selected for monitoring: existing municipal or private wells, and new test and observation wells recently installed by Brown and Caldwell. All of the newly test and observation wells will be sampled for this study. Only a selected group of existing municipal and private wells were selected from each municipality for use in this monitoring program. The rational for choosing the existing wells included the following criteria:

- Geographic location—no more than one well per square kilometer was chosen to provide enhanced spatial distribution over the study areas.
- Proximity to Contamination—priority was given to wells located in areas that are assumed to be beyond the extent of agricultural or industrial contamination.
- Depth of the Screen—priority was given to wells screened in deeper aquifers with less chance of contamination from outside sources.
- Daily Use of Well—a representative number of wells that are heavily used and wells that are not pumped often were selected for the monitoring program.
- Use of Water—a representative number of wells used for residential, industrial and agricultural purposes were selected for this monitoring program.

In total, it is proposed to monitor and sample 52 wells for the survey. These wells consist of:

- 14 wells in Villanueva (nine existing wells and five newly installed wells)
- 17 wells in Choloma (14 existing wells and three newly installed wells)
- 12 wells in La Lima (nine existing wells and three newly installed wells), and
- 9 wells in Limon de la Cerca (six existing wells and three newly installed wells)

These wells are listed individually in Tables 1 through 4, and located on the figures in Chapter 3 of the report. It is important to note that the same wells will be sampled during each monitoring event to provide consistency in data and allow for ease of tracking trends in data over time.

3.2 General Groundwater Level and Sampling Procedures

The groundwater level and monitoring program has several components that are essential to support and enhance the groundwater modeling effort as well as provide a base of historical data that can be tracked over time. These components include groundwater level data collection, water sample collection, analysis of water samples, and review, compilation and understanding of water chemistry results. Each of these components is descried separately below.

3.2.1 Groundwater Level Data Collection. Groundwater levels will be measured so that changes in groundwater elevations can be documented and analyzed over time. For example, analysis of groundwater elevations over time can reveal seasonal trends. To collect groundwater levels, field personnel lower an electronic water level indicator down the well until groundwater is encountered (indicated by a beeping noise from the equipment). This depth to groundwater is then recorded in the log book. The water level measurement will be converted into an elevation by subtracting the depth to water from the well surface elevation. A more detailed description of the procedure for collecting groundwater level data is provided later in this text.

3.2.2 Groundwater Sampling. Following collection of the groundwater level measurement, a water sample will be collected. At a minimum, all wells included in this program will be sampled and analyzed for general chemical parameters, pH, electrical conductivity, bateriology and heavy metals. All wells in the monitoring program will also be analyzed for gross alpha and gross beta to establish the presence or absence of radiological compounds. Any of these minimum analytical parameters that are not detected in large quantities in the initial sampling event will be considered for elimination from future monitoring events.

In addition to analyzing for the minimum parameters described above, other important water quality parameters, including pesticides/herbicides and volatile organic compounds (VOCs), should be considered on a well-by-well basis. Sampling and analysis for these parameters will be based on information such as local land use and proximity to industrial activities. For example, the Caneras well fields in Villanueva will likely be sampled and analyzed for the presence of pesticides and herbicides because they are located within a sugar cane plantation. In Choloma, Well Colonial Canada is located near industrial runoff sources, and will likely be sampled and analyzed for VOCs.

Tables 2 through 5 provide a list of suggested monitoring parameters for each well included in this monitoring program.

3.2.3 Groundwater Chemical Analysis. After collecting groundwater samples from each well, the samples will be transported to the laboratory for analysis. For the initial sampling, conducted by Brown and Caldwell, some of the samples will be shipped to Southern Petroleum Laboratory in Houston, Texas, United States of America and some will remain locally in Honduras at Jordanlab located in San Pedro Sula.

3.2.4 Laboratory Data Review and Compilation. When the laboratory has completed the analysis of the samples, the data must be reviewed and compiled. For the initial sampling conducted by Brown and Caldwell, a chemist in the Sacramento, California office will evaluate the data and the data will be input into a project database. For subsequent sampling efforts, each municipality must assess the analytical data separately — look for trends with historical data, be aware of constituents that exceed health based guidelines, and perform quality assurance measures to verify the accuracy of the laboratory data. Once the data have been reviewed for accuracy and consistency, the data should be input into the database provided by Brown and Caldwell and the original copies from the laboratory filed for future reference.

3.3 Quality Assurance/Quality Control

Specific Quality Assurance/Quality Control (QA/QC) steps will be taken in the field and by the laboratory in order to document and ensure that the analytical data have the maximum amount of integrity. The QA/QC program for the groundwater monitoring will include collecting Quality Control samples, use of qualified laboratories, a specific laboratory reporting format, review of laboratory data packages, and consistency in sample identification. These QA/QC items are reviewed below:

- Samples will be carefully labeled with sample designation, the initials of the sampler, and the analysis to be performed. Date and time of sample collection will be added s the sample is collected.
- Field personnel involved in sample collection will wear disposable gloved to prevent potential contamination of samples. Gloves will be discarded after sampling each well.
- Groundwater samples collected from wells with dedicated pump systems will be collected with minimal potential agitation of the sample between the adductor pipe outlet and sample containers. All samples should be collected as closely as possible to the well head.
- Sampling heads should be constructed of non-metallic material, preferably polyethylene or Teflon®. Before collection of samples at all stations, the sampling heads will be cleaned in a non-phosphatic detergent and rinsed with tap water. This will be followed with a distilled-deionized water rinse.
- Groundwater samples collected from monitoring wells without dedicated pump systems will be collected with disposable Teflon or polyethylene bailers and nylon cord. The bailer and cord will be disposed of after the sample has been collected.
- Sample bottle guides for all parameters (bottle type, volume of sample needed, and type of preservatives used) are given in Table 3.

- Samples collected for dissolved metals will be filtered and preserved in the field.
- Immediately after collection of the sample is completed, the sample will be placed in a cooler at 4 degrees C.
- All pertinent information generated during the groundwater sampling event will be recorded on the Field Data Form and in the field log book.
- Duplicate samples will be collected as needed and are intended to be identical to the original sample. A field duplicate sample will originate from the project site and be in a separate sample container. Duplicates will be taken for approximately every 10 percent of samples collected during the sampling event, or a minimum of one per municipality per monitoring event. The location for duplicate sample collection will be determined prior to the sampling round.
- Equipment blanks will not be required because samples will be collected using dedicated pumps and disposable filters and bailers.
- Trip blanks will be provided by the laboratory whenever analysis of volatile compounds occurs.

3.3.1 Quality Control Samples. During each monitoring event, one blind duplicate sample will be collected from each municipality. A blind duplicate sample is a second sample collected from a predetermined well that is given a new (false) name so the laboratory does not know which well the sample is from. This method is commonly used to verify the accuracy of laboratory reports. In addition, a trip blank will be included in every cooler that is used to transport samples to be analyzed for VOCs. It is strongly recommended that this practice continue for all subsequent sampling events completed by the municipalities. A list of the wells that have been selected for duplicate sampling is illustrated in Tables 5 through 8.

3.3.2 Laboratory Qualifications. All chemical analyses will be performed by a laboratory certified by the USEPA or the Government of Honduras. Analytical methods and SOPs that are acceptable, in accordance with EPA recommendations, will be consistently maintained by the laboratory to satisfy the required QA/AC protocol.

3.3.3 Laboratory Data Packages. All results from USAID groundwater samples will be reported in modified Level 3+ QC data packages that provide the following documentation: sample chain-of-custody, method blank results, matrix spike/spike duplicate summary results, and detection limits listed on all reports. Data packages including all surrogate recoveries, laboratory control samples, initial and continuing calibrations, run logs, extraction logs, and correction action reports will be obtained from the laboratories as needed for individual samples.

3.3.4 Sample Naming Convention. For this groundwater level and monitoring program, the naming system will consist of three components: well name, month of the sampling event, year of the sampling event. For example, for the well named Cañeras 2 in Villanueva that will be sampled in October 2001 the sample name will be Cañeras 2 102001. It is important to follow this naming protocol so all samples have a unique identifier when they are entered into the database.

3.4 Schedule

The initial round of monitoring and sampling is scheduled for late October 2001. Sampling activities will be completed for one municipality prior to beginning sampling at the next municipality. This practice will be maintained in future monitoring events to reduce data analysis issues that may arise from weekly, monthly and seasonal changes in the water system. For the initial round of sampling, field work is anticipated to begin in Choloma and then move to Villanueva and La Lima. Finally, the samples will be collected in Limon de la Cerca.

4.0 DETAILED PROCEDURES

The following narrative provides a step-by-step outline of the activities necessary to complete the groundwater level and monitoring program. These steps should be followed each time groundwater samples are collected to ensure accuracy, consistency, and representativeness of data collected during this program.

4.1 Sampling Team and Responsibilities

The sampling team will consist of both field and office personnel. Each person on the team will have specific duties and responsibilities as described below.

- **Sampling Coordinator.** The sampling coordinator will have the overall responsibility for the sampling program and will be responsible for timing and scheduling of the sampling events, oversight of the sampling crew, and liaison with the laboratories. In order to respond to the changing requirements of the project, the sampling coordinator may, after consultation with the project manager, adjust the number and locations of samples to be collected, and the analytes for each sample.
- **Field Sampling Crew.** The field crew may consist of either two or three persons depending on the number of samples to be collected, and the time span allowed for that sampling. The field sampling crew will report directly to the sampling coordinator, and will be responsible for the physical collection of the samples according to the protocol described in this SAP.
- **Quality Assurance (QA) Reviewer.** This person will perform a detailed review of all data generated by this sampling program. The person will chart and document the water quality and will compare the analytical results to acceptable standards as they are available. After the results of each sampling event are reviewed, they will be compiled and a short data report will be prepared for each municipality for use by the project manager to document the results, any deviations from standards, and trends that may occur.

To ensure valid water chemistry determinations, the procedures outlined herein are based on guidelines established by the United States Environmental Protection Agency (USEPA, 1986) in the Code of Federal Regulations (40 CFR 100-149) and the U.S. Geological Survey (USGS, 1984).

4.2 Water Level Measurements

The following steps will be used to obtain water level measurements:

- On arrival at the wellhead, condition of the surface seal and protector or well cover will be checked and observations will be recorded in the field book.
- The area around the well will be cleared prior to unlocking the protector or well cover and removing the cap from the top of the well.
- Before taking any measurements, any previous data of water levels for the well will be reviewed.
- Measuring points will be established based on historical information. If no information is available, a notch on the north side of the well casing or the top of the sounding tube will be used.
- Each well will be sounded three times for depth to water with an electronic water sounder. Water level measurements will be continued until a difference of less than 0.02 feet between consecutive measurement is obtained.
- Depth to water and date of measurement will be recorded on the Field Data Form.
- The previous measured water level will be reviewed. If the difference between the current water level and historical water level measurement is greater than 1 foot, the current measurement will be rechecked.

Smoking, eating, or drinking in the vicinity of the well head, pump output, or field analytical setups will be forbidden in order to eliminate the potential for induced contamination.

Water level data will be collected and documented on the field sheet provided as Appendix A to this sampling manual.

4.3 Well Purging

Well purging activities include the following items:

- A minimal volume of water will be purged, taking into consideration the local hydrologic factors together with the stabilization of pH, temperature, and electrical conductance (EC) over at least two to three borehole volumes. The wells are expected to have very low-flow rates. Purging will possibly draw the water level down to a point that the pump will shut off due to lack of water. When this occurs, the well will be allowed to recover 80 percent of the original static water level, or for 24 hours. Sampling will proceed when these recovery conditions have been met.
- Readings of pH, temperature, and EC, will be recorded, and the cumulative volume pumped will be measured and recorded.
- Purge water will not be containerized but will be discharged directly to the surrounding ground surface.

4.4 Field Tests

During groundwater and surface water sampling activities, the following field tests will be conducted:

- Measurement of pH, temperature, EC, and depth to water in the well to be sampled will be taken and recorded immediately before and after collection of each groundwater sample.
- Conductivity, pH, and temperature meter probes will be thoroughly rinsed with distilled water prior to each use.
- The pH meter will be calibrated in pH 4 and pH 10 buffer solutions at the beginning and end of each sampling day. Calibration data will be recorded on the Field Data Form and in the field log book.
- The conductivity meter will be calibrated using manufacturer specified solutions before and after the sampling. Calibration data will be recorded on the Field Data Form and in the field log book.
- All field parameters will be collected and documented on the field data sheet provided as Appendix A to this sampling manual.

4.5 Groundwater Sample Collection

In order to ensure that proper groundwater samples are collected, the following items are required:

- The laboratory will be contacted at least two working days before receipt of the samples to establish a schedule for sample analysis. The following information will be provided for the laboratory:
  --approximate number of samples the laboratory will be receiving;
  --parameters to be tested;
  --holding time; and
  --number and types of sample bottles to be provided to the laboratory.
- All sample containers obtained from the laboratory shall be factory new. The exception to this is the jars received from JordanLabs in San Pedro Sula, Honduras for fecal and total coliform. These jars will be sterilized by way of an autoclave.
- An adequate number of forms will be obtained for documentation of field activities.
- Groundwater sample collection will be scheduled and performed to accommodate the required laboratory holding times, and to ensure that a maximum representation of the aquifer condition.

4.6 Sample Containers and Preservatives

Sample containers and appropriate sample preservatives will be provided by the laboratories performing analytical services. All container preparation by the laboratory will be done in a designated area. Containers will be labeled to indicate the added preservative. A full list of sample containers and preservatives for this project can be reviewed in Tables 2 through 5. Preparation is accomplished using the following SOPs for bottle preservation:

- Bottles for organic analyses will be provided by the laboratory. These will be purchased from suppliers who certify the containers to have been cleaned by protocols as prescribed in the Environmental Protection Agency (EPA) methods for organic analyses.
- Coolers, and applicable chain-of-custody forms will also be provided by the laboratories. Brown and Caldwell will be responsible for the purchase of bulk block ice that is appropriate for overseas shipping. Blue ice will not be used for cooling samples on this project.
- All sample containers with appropriate preservatives and coolers will be delivered at lease one week prior to sample collection.
- After a sample is collected, preserved, and labeled, it will be stored on ice at 4 degrees C in a plastic ice chest. No ice chest will be allowed to stay in the field beyond its ability to keep the temperature at 4 degrees C.
- All samples will be wrapped in plastic packing when necessary to avoid breakage, and will be clearly labeled and sealed to prevent tampering.
- All samples will have a label containing (at a minimum) the following information:
  --Sample designation;
  --Project name and number;
  --Date and time of collection; and
  --Comments – These may include parameters to be analyzed, whether the sample is filtered or unfiltered water, and any preservatives added to the sample.

4.7 Chain-of-Custody

Chain-of-Custody procedures will include:

- Samples collected by field personnel will be accompanied by a Chain-of-Custody Record Form, which will include date and time of collection, container type, preservatives used, number of samples, sample descriptions, and others.
- Sample identification labels and chain-of-custody records will be completed with waterproof ink, and placed in a waterproof bag for shipment.
- Chain-of-Custody documentation will be completed at each sample location prior to sampling at the next well.
- Samples will be hand delivered to JordanLabs in San Pedro Sula the day of the sampling. Samples that are being analyzed by Southern Petroleum Laboratory (SPL) in Houston, Texas will be delivered via DHL overnight shipment service. It should be noted that coliform samples have a short holding time of only 24 hours. It is imperative that field crew communicate with JordanLabs prior to sampling to verify that the analysis can be run in the appropriate time frame.
- The integrity of the samples will be examined, and the final signature of the Chain-of-Custody form will be completed by a receiving agent of the selected laboratory.
- A sample chain-of-custody is provided as Appendix B to this sampling manual.

5.0 DATA MANAGEMENT

Field and laboratory data management, data review, and reduction are given below to create a centralized working system, and to maintain data quality.

- Field Data. Water quality records for each sampling location will be produced, copied, and filed under the appropriate category for each groundwater quality well. Records completed in the field will include physio-chemical (pH, temperature, EC) parameters of groundwater and chain-of-custody records. These forms will be forwarded by the field manager to the project manager at the conclusion of the sampling effort.
- The following field documentation will be completed by the field personnel:
  --Complete entry in dedicated field notebook;
  --Complete the Field Data Form, and one Chain-Of-Custody Form.
- Laboratory Data. Analytical results and QC data relating to analytical precision and accuracy will be obtained from the laboratory. Laboratory analytical result data sheets will be specific to sampling location and method of analysis. The original Chain-Of-Custody Forms will be filed with the analytical results. Data will be organized with respect to date, original water quality results, and QA/QC results.
- Data Review. Field data will be reviewed for measurements collected during sampling, order of sample collection , and the observations and notes recorded during he course of the sampling day. Laboratory data forms will be reviewed for the completion of required measurements, including parameter results, limits of detection, and dilution factor. Validity of both the field and laboratory data will be determined by evaluating the completeness of the data for the required parameters as documented on the chain-of-custody form.
- The following data will also be reviewed:
  --Use of EPA methods with detection limits below water standards, where applicable;
  --Chemical data of control matrix blanks, control matrix spikes, standards, control matrix duplicates; and
  --Confirmation of sample analyses within specific holding times.

6.0 REPORTING

A general assessment of the groundwater and surface water quality for the fall of 2001 will be submitted to USAID in the final report presented at the termination of the project. It will be the responsibility of each municipality to report the water quality results to the appropriate individuals after each sampling event in the future.

7.0 GLOSSARY OF TERMS

Aquifer: The geological stratum that can produce enough water to support consumption. It is the section of the well where screening in a well is installed.

Bailer: a PVC tube one meter long used to collect water samples from wells that do not have a pump installed.

Casing: PVC or steel tubing installed into a borehole with perforated sections and non-perforated sections used to capture the water from an aquifer.

Chain-of-Custody: a legal document used to track groundwater samples. A chain-of-custody includes information such as the name of the sample, the date of collection, the time of collection, the name of the technician and the analysis requested by the laboratory. A chain-of-custody should remain with the samples at all times.

Database: A computer system used to archive historical data.

Drawdown: the difference, measured in feet or meters, between the water table or static water level and the level of the water after pumping.

Electrical Conductivity: a chemical parameter that quantifies the potential for water to conduct or carry electricity. Electrical conductivity is a function of the the quantity of dissolved minerals (particularly salt) in the water.

General Bacteriology: water quality analysis performed to determine the presence of bacteria and sometimes to determine the amount of fecal material present in a sample.

Holding Time: the amount of time between sample collection and when a laboratory needs to analyze the sample. For example, for fecal coliform samples, less that 24 hours can pass between sampling activities and analysis or the data will be invalid.

JORDANLAB: analytical laboratory in San Pedro Sula used to analyze samples for the USAID project.

Preservatives: chemicals—typically acids—added to sample bottles collected in the field to increase the time allowable between sampling and analysis. Preservatives are also used to retain potential contaminants in the sample so the laboratory can get a true understanding of what is in the water.

Radiological Chemicals (Gross a, Gross ß): chemical parameters used to demonstrate the amount of radiological chemicals in a sample.

Screening: the portion of PCV or steel casing that is perforated to allow the passage of aquifer water into the well.

Sounder: a device used to determine the level of water in the well. It measures feet or meters below ground surface.

SPL: Southern Petroleum Laboratories, laboratory used for the USAID Groundwater Resources Study for metals, radiological chemicals, pesticides and herbicides and VOCs.

Static Water Level: the level at which water stands in a well or unconfined aquifer when no water is being removed from the aquifer etiher by pumping or free flow.

QA/QC: Quality Assurance/Quality Control, a method of checking data to be sure it is valid.

Volatile Organic Chemicals: man-made organic chemicals that are widely used for industrial and domestic purposes including solvents for cleaning and pesticides/herbicides.

Tabla No.1 Pozos seleccionados para muestreo en los municipios de Villanueva, La Lima, Choloma

Nombre del Pozo	Municipio	UTM	Q GPM	Fuente de contaminación	Profundidad del Pozo (Pies)	Profundidad Rejilla (pies)	Llave para muestreo	Elevación Terreno natural	Sector abastecido No. de Viviendas Abastecidas	Producción Diaria (Gal)
La Victoria	Villanueva	16P 0394395 1693962	120	Ninguna	195		SI	67.3278	Col. La Victoria 543	172,800
Pintala I	Villanueva	16P 0392752 1691490	400	Ninguna	240	41	SI	53.3728	Col. 1 de Mayo y San Antonio 96	48,000
Manuel Coello	Villanueva	16P 0394328 1692334	202	Ninguna	270	49	SI	50.1758	A tanque Col. Victoria y Col. Sitiahmacs 543	115,140
Villa Linda Norte	Villanueva	16P 0394962 1695873	105	Letrinas a 10 metros	300	25	SI	54.1698	Col. Villa Linda Norte 144	25,200
Villa Sol	Villanueva	16P 0393671 1693850	27.24	Ninguna	184		SI	78.8138	Parte de la Col. Villa Sol 40	37,591
Cañeras II	Villanueva	16P 0393345 1691699	600	Ninguna	250	100	SI	47.2048	Conectado al Plan Maestro (Red baja y alta) 3369	864,000
Guadalupe Lopez	Villanueva	16P 0396098 1693853	150	Letrinas a 10 metros	260	70	SI	70.7248	Tanque 21 de Abril 315	216,000
22 de Mayo	La Lima	16P 0391650 1709438	90	Letrinas a 5 metros	180		SI	29.238	Tanque Col. 22 de Mayo 105	97,200
Villa Esther	La Lima	16P 0402604 17006467	200	Canal de aguas negras a 100 metros	260	154	SI	26.83	Residencial Villa Esther 9	252,000
Oro Verde	La Lima	16P 0403573 1705732	298	canal de aguas negras a 100 metros			SI	25.43	Residencial Oro Verde y Zip Continental	
Guaymuras	La Lima	16P 0397437 1708534	100	Letrinas a 30 metros	362		SI	28.937	A Tanque Guaymuras 155	108,000
Planeta #1 (Fusep)	La Lima	16P 0398234 1709076		Ninguna	200	40	SI	28.091	Red de la Col. Planeta 2312	
La Mesa (Nuevo)	La Lima	16P 0401055 1708035	400	Ninguna	200	63		27.755	Col. La Mesa NO HAY BOMBA	
Cruz Roja	La Lima	16P 0400429 1707065	150	Ninguna	200	150	SI	27.87	A la red del Centro de Lima Vieja	162,000
Martinez Rivera	La Lima	16P 0400140 1705694	150	Ninguna	180		SI	28.993	Tanque de la Col. Martinez Rivera 101	162,000
San Carlos	Choloma	16P 0399179 1726619	296	Ninguna	176	41	SI	26.223	Tanque de la Col. San Carlos 885	337,400

Nombre del Pozo	Municipio	UTM	Q GPM	Fuente de contaminación	Profundidad del Pozo (Pies)	Profundidad Rejilla (pies)	Llave para muestreo	Elevación Terreno natural	Sector abastecido No. de Viviendas Abastecidas	Producción Diaria (Gal)
Prado I	Choloma	16P 0399065 1728223	60	Quebrada con aguas negras a 75 metros	100		SI	26.298	Tanque de la Col. Prado I 161	14,400
Residencial Europa	Choloma	16P 0399366 1725680	225	Ninguna	117		SI	24.423	Tanque de la Col. Europa 389	283,500
San Antonio	Choloma	16P 0397599 17267087	450	Contaminación por infiltración de heces fecales	120	60	SI	33.852	A la red del centro de Choloma	648,000
Bella Vista	Choloma	16P 0398794 1725376	196.2	Quebrada contaminada por aguas negras 400 metros	200		SI	27.282	Sector Sur (Sector López Arellano) 2751	282,528
Bomberos I	Choloma	16P 0397867 1726032	257.2	Ninguna	200	40	SI	32.422	Sector SE, SO, NE de Choloma	370,368
San Francisco	Choloma	16P 0397287 1726970	100	Quebrada contaminada por aguas negras a 1 metro	80		SI	37.315	Col. Los Almendros y Col. Care 439	108,000
Barrosse II	Choloma	16P 0398472 1728223	587	Ninguna	200	60	SI	25.813	Sector N.O. de Choloma	845,280
Victoria (Gas. Depesa)	Choloma	16P 0397645 1721746	68	Ninguna	329	40	SI	52.523	A tanque Col. La Victoria 90	24,480
Canada	Choloma	16P 0397831 1725769	400	Canal de aguas negras a 30 metros y quebrada contaminada con aguas negras y desechos de fabricas a 150 metros	200		SI	31.992	A la red de la Col. Canadá 127	576,000.00
Parque Central	Choloma	16P 0397918 1726067	350	Ninguna	200		SI	32.077	A la red del centro de Choloma	420,000
Primavera	Choloma	16P 0397194 1726282	180	Ninguna	200		SI	36.434	Col. La Primavera 312	259,200

Tabla No. 2 Método Analítico, Envase, y Especificaciones de Control de Calidad para Villanueva, Cortés, Honduras.

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	No. de Envases	Preservantes	Duplicado	MS	MSD
Cañeras 2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
	A.S.	Pesticidas/Herbicidas	32 oz. Ámbar	2	Ninguno			
Pintala 1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Pintala 2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Plástico	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Guadalupe Lopez 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno	X	X	X
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno	X	X	X
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio	X	X	X
Manuel Coello 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Colonia Victoria 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Plástico	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Villa Linda Norte	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
BC-VI-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
BC-VI-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Plástico	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-VI-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-VI-4 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Total a, Total ß	32 oz. Plástico	2	Ácido Nítrico			
BC-VI-5 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No.3 Método Analítico, Envase, y Especificaciones de Control de Calidad para Choloma, Cortés, Honduras.

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	Número de Envases	Preservantes	Duplicado	MS	MSD
Parque Central 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Bomberos 1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Bella Vista 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Perez Estrada 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
San Carlos 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Res. Europa 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Col El Prado II 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Barrosse 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno	X	X	X
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno	X	X	X
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio	X	X	X
San Antonio 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
San Francisco 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
La Primavera 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
Victoria 1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
Inez Carranza Barnica 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
Res. América 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-CH-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-CH-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Total a, Total ß	32 oz. Plástico	2	Acido Nítrico			
BC-CH-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No.4 Método Analítico, Envase, y Especificaciones de Control de Calidad para La Lima, Cortés, Honduras

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	Número de Envases	Preservantes	Duplicado	MS	MSD
Don Lolo 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Oro Verde 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Martínez Rivera 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
22 de Mayo 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Guaymuras 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Villa Esther 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Planeta Fusep 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno	X	X	X
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno	X	X	X
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio	X	X	X
Cruz Roja 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Vivero Municipal 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml Plástico	2	Filtrado en el laboratorio			
BC-LL-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	32 oz. Plástico	2	Ninguno			
	A.S.	Metales	40 ml Plástico	2	Filtrado en el laboratorio			
BC-LL-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml Plástico	2	Filtrado en el laboratorio			
	A.S.	Total a, Total ß	32 oz. Plástico	2	Ácido Nítrico			
BC-LL-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml Vidrio	2	Ninguno			
	A.S.	Metales	40 ml Plástico	2	Filtrado en el laboratorio			

Tabla No.5 Método Analítico, Envase, y Especificaciones de Control de Calidad para Limón de la Cerca, Choluteca, Honduras.

Nombre de la Muestra	Matriz	Analitos/Análisis	Tipo de Envase	Número de Envases	Preservantes	Duplicado	MS	MSD
Panamerica LC4 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Bolsa Samaritana LC3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Ricardo Soriano LC1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Iglesia Cristo Rey 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Atlas LC2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
Luis 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	32 oz. Plástico	2	Filtrado en el laboratorio			
BC-LC-1 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
BC-LC-2 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			
	A.S.	Totala, Totalß	32 oz. Plástico	2	Ácido Nítrico			
BC-LC-3 102001	A.S.	Química General	32 oz. Plástico	1	Ninguno			
	A.S.	Bacteriológico	100 ml. Vidrio	2	Ninguno			
	A.S.	Metales	40 ml. Plástico	2	Filtrado en el laboratorio			

Tabla No. 6 Red de Monitoreo de Pozos
La Lima, Honduras

No	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (m snm)	Elevación Nivel de Referencia (m snm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estatico (m)	Fecha lectura	Observaciones
1	Colonia Fraternidad	16P 0399855 1707090	Observación	28.06	28.38	15.00	04-Oct-01			
2	Los Maestros	16P 0400224 1707203	Monitoreo	27.19	27.62	6.79	06-Sept-01			
3	El Mixto	16P 0400700 1706883	Procucción	28.51	29.42	6.67	04-Jan-02			
4	Cruz roja	16P 0400469 1707065	Procucción	27.87	28.37	12.88	04-Jan-02			
5	Sitraterco	16P 0400587 1707306	Procucción	27.57	28.01	8.56	04-Jan-02			
6	Martínez Rivera	16P 0400135 1705691	Procucción	28.99	29.05	4.54	04-Jan-02			
7	Gabriela Mistral	16P 0400294 1706908	Procucción	28.45	29.11	5.64	06-Jan-01			
8	Zapote No.1	16P 0398158 1706728	Procucción	31.09	31.75	4.95	04-Jan-02			
9	Zapote No.2	16P 0397798 1706836	Procucción	30.57	31.17	3.35	04-Jan-02			
10	Planeta No.1 (Fusep)	16P 0398803 1708994	Procucción	28.09	28.39	5.97	04-Jan-02			
11	Planeta No.3	16P 0398284 1709356	Procucción	27.89	28.16	6.46	04-Jan-02			
12	FHA No.1 (Fuerza Aérea Hondureña)	16P 0399594 1707531	Monitoreo	27.41	27.98	5.50	04-Jan-02			
13	FHA No.2 (Fuerza Aérea Hondureña)	16P 0399624 1707517	Monitoreo	27.31	27.61	4.10	04-Jan-02			
14	Aeropuerto	16P 0399349 1707864	Monitoreo	26.51	26.67	6.67	04-Jan-02			
15	Jerusalem No.1	16P 0397548 1709059	Procucción	28.48	28.76	5.50	04-Jan-02			

No	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (msnm)	Elevación Nivel de Referencia (msnm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estatico (m)	Fecha lectura	Observaciones
16	Jerusalem No 2 (Kinder)	16P 0397368 1708923	Procucción	28.42	28.60	7.10	04-Jan-02			
17	Guaymuras	16P 0397437 1708534	Procucción	28.94	29.99	8.85	04-Jan-02			
18	San Cristobal	16P 0397715 1708758	Procucción	29.37	31.45	13.60	04-Jan-02			
19	La Paz No 2 (Luis Thiebaud)	16P 0400263 1706706	Procucción	25.90	26.41	7.21	04-Jan-02			
20	Oro Verde	16P 0403573 1705732	Procucción	25.43	25.72	4.02	04-Jan-02			
21	Villa Esther	16P 0402604 1706467	Procucción	26.83	27.11	9.25	04-Jan-02			

Tabla No. 7 Red de Monitoreo de Pozos
Choloma, Honduras

No.	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (msnm)	Elevación terreno Referencia (msnm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estático (m)	Fecha lectura	Observaciones
1	San Francisco	16P 0397287 1726970	Producción	37.32	37.66	5.97	17-Dec-01			
2	San Antonio	16P 0397599 1726708	Producción	33.85	34.39	5.14	17-Dec-01			
3	Primavera	16P 0397194 1726282	Producción	36.43	36.68	5.74	17-Dec-01			
4	Prado I	16P 0399065 1728223	Producción	26.30	26.49	5.92	05-Dec-01			
5	Prado II	16P 0399065 1725620	Producción	25.61	26.21	5.76	05-Dec-01			
6	Residencial El Japón	16P 0400206 1725865	Producción	21.42	21.77	4.27	05-Dec-01			
7	Inés carranza Barrica	16P 0398277 1720762	Producción	42.23	42.74	13.86	18-Dec-01			
8	Bomberos I	16P 0397867 1726032	Producción	32.42	33.61	9.90	17-Dec-01			
9	Residencial San Carlos	16P 0399179 1726619	Producción	26.22	26.30	4.92	05-Dec-01			
10	Residencial América	16P 0399292 1726913	Producción	26.92	27.26	3.98	05-Dec-01			
11	Victoria #1 (gasolinera)	16P 0397645 1721746	Producción	52.52	52.94	21.32	18-Dec-01			
12	Residencial Europa	16P 0399366 1725680	Producción	24.42	24.92	4.10	05-Dec-01			
13	Canadá	16P 0397831 1725769	Producción	31.99	33.87	9.61	17-Dec-01			
14	La Mora No.1	16P 0396909 1725541	Producción	35.78	35.96	10.77	18-Dec-01			

Tabla No. 8 Red de Monitoreo de Pozos
Villanueva, Honduras

No.	Nombre del pozo	Coordenadas UTM	Tipo de pozo	Elevación terreno Natural (msnm)	Elevación terreno Referencia (msnm)	Nivel Estático anterior (m)	Fecha lectura	Nuevo Nivel Estático (m)	Fecha lectura	Observaciones
1	Orquidea II	16P 0393142 1694141	Producción	92.66	92.82	33.80	29-Nov-01			
2	Orquidea III	16P 0393034 1694095	Producción	94.51	94.95	43.56	29-Nov-01			
3	Col. Municipal	16P 0395157 1694522	Producción	64.93	65.50	10.60	29-Nov-01			
4	Buena Vista	16P 0395939 1693554	Producción	71.48	72.09	34.43	29-Nov-01			
5	Villa Linda Norte	16P 0394962 1692873	Producción	54.51	54.96	13.50	29-Nov-01			
6	Guadalupe Lopéz	16P 0396098 1693853	Producción	71.10	71.40	30.17	29-Nov-01			
7	La Victoria	16P 0394395 1693962	Producción	67.98	68.76	32.66	29-Nov-01			
8	Cañeras II	16P 0393445 1691699	Producción	47.51	47.91	10.94	06-Julio-01			
9	Pintala I	16P 0392752 1691490	Producción	53.37	53.78	8.77	29-Nov-01			
10	Villasol	16P 0393671 1363850	Producción	71.81	72.04	28.17	30-Nov-01			
11	Independencia I	16P 0393832 1693445	Producción	72.52	73.02	23.00	30-Nov-01			
12	Manuel Coello	16P 0394328 1692334	Producción	50.18	50.56	14.57	20-Nov-01			
13	Vivero Municipal	16P 0393415 1694607	Producción	97.28	97.48	32.64	29-Nov-01			
14	Llanos de Canadá	16P 0395814 1692807	Producción	52.00	52.84	6.49	19-Julio-01			
15	Zip Villanueva #6	16P 0394991 1694016	Producción	61.73	63.93	18.32	18-Julio-01			

APPENDIX A

Field Form

WATER SAMPLE DATA LOG

Project No.:	Project:
Well No.:	Date:
Location:	Weather:
Purpose of Sampling Event:	

WELL DATA

Total Depth of Well (ft bls):	Depth to Water (ft bls):
Screened Interval (ft bls):	Date/Time:
Casing Diameter (in):	Pt. of Measurement:

FIELD SAMPLING DATA

Time	Discharge Rate (gpm)	Total Discharge (gallons)	pH	Temp. °F	Specific Conduct. (µmhos/cm)	Sand Content (mℓ/ℓ)	Comments

Time Pumping Started: ____________ Time of Sample Collection: ____________

Type of Samples Collected: ____________

Total Discharge (gpm): ____________ Type of EC-T-pH Meter: ____________

Sample Collected by: ____________

How Sample Collected: ____________

Comments: ____________

APPENDIX B

Chain of Custody

SPL, Inc.

Analysis Request & Chain of Custody Record

SPL Workorder No: 104520

page 1 of 1

Client Name: Brown & Caldwell
Address/Phone: Barbara Goodrich
Client Contact: 925-937-9010
Project Name: USAID Groundwater Monitoring
Project Number: 21365
Project Location: Villanueva, Cortés, Honduras
Invoice To: Brown & Caldwell, Walnut Creek

matrix: W=water S=soil SL=sludge O=other:
bottle: P=plastic A=amber glass G=glass V=vial
size: 1=1 liter 4=4oz 40=vial 8=8oz 16=16oz
pres.: 1=HCl 2=HNO3 3=H2SO4 O=other:

SAMPLE ID	DATE	TIME	comp	grab	matrix	bottle	size	pres.	Number of Containers	metales	coliformes	VOCs						
nombre de muestra	11/30/2001	1420		X	W	P	1	–	1	X								
nombre de muestra	11/30/2001	1425		X	W	G	16	1	1		X							
nombre de muestra	11/30/2001	1425		X	W	G	40	3				X						

Barbara Goodrich

Client/Consultant Remarks:

Laboratory remarks:

Intact? ☐ Y ☐ N

Temp:

Requested TAT

☐ 24hr ☐ 72hr
☐ 48hr ☒ Standard
☐ Other ______

Special Reporting Requirements: Fax Results ☒ Raw Data ☐
Standard QC ☒ Level 3 QC ☐ Level 4 QC ☐

Special Detection Limits (specify):

PM review (initial):

	date	time	
1. Relinquished by Sampler: Barbara Goodrich to DHL	11/30/2001	1750	2. Received by:
3. Relinquished by:	date	time	4. Received by:
5. Relinquished by:	date	time	6. Received by Laboratory:

☒ 8880 Interchange Drive, Houston, TX 77054 (713) 660-0901
☐ 500 Ambassador Caffery Parkway, Scott, LA 70583 (318) 237-4775
☐ 459 Hughes Drive, Traverse City, MI 49684 (616) 947-5777

APPENDIX C

Groundwater Sampling Event Checklist

CHECKLIST FOR GROUNDWATER SAMPLING EVENT

Before leaving for the field:

1. Contact the laboratory responsible for bacteriological analysis before sampling event.
2. Arrangements made for international transport of water samples.
3. Access to well and proper pump function have been verified before water sample.
4. The following materials and equipment are available:
   Electronic water level meter
   Field meter for conductivity, pH, and temperature
   Field meter calibration solutions
   Water sample containers (supplied by laboratory)
   Ice chests
   Ice
   Water sample labels
   Disposable gloves
   Zipper-lock plastic bags
   Water sampling field forms
   Chain of custody form
   Camera and film
   Sample packing material
   Water sample field filtering equipment
   Flame disinfection equipment
5. Confirm proper function of the electronic water level meter

In the field:

1. Observation and proper documentation of conditions at the well site prior to sampling.
2. Locate elevation reference point for water level measurement.
3. Conduct three consecutive measurements of groundwater level and record results on the field data form.
4. Disinfection of the sampling port using flame.
5. Proper purging of three well volumes before water sampling.
6. Calibration of the field conductivity, pH, and temperature meter.
7. Measurement of conductivity, pH, and temperature and documentation in field form.
8. Water sampling personnel use disposable gloves during water sampling.
9. Collection of the necessary quantity of groundwater for each analysis.
10. Samples for iron and magnesium analysis were filtered in the field.
11. Sample containers for volatiles analysis were free of bubbles.
12. Sample date and time are recorded and documented on field form.
13. All samples are properly labeled.
14. Chain of custody documentation is filled out prior to sampling of next well.
15. Periodic confirmation that water sample ice chest contains sufficient ice to maintain a temperature not greater than 40 C.

After water sampling:

1. Water samples for bacteriological analysis were delivered to the laboratory within the appropriate holding time.
2. The laboratory signed the chain of custody for receipt of water samples.
3. Water samples for shipment were carefully packed in protective material, preferably bubble-wrap.
4. Ice for the ice chest is placed in zipper-lock plastic bags to avoid spilling.
5. Water samples and ice are placed in a large plastic bag within the ice chest.
6. The signed and dated chain of custody is placed in the ice chest for shipping.
7. The ice chest was carefully sealed prior to shipping.
8. An international air bill and a commercial invoice are filled out to accompany the ice chest during shipping and transport.
9. The laboratory in Houston was contacted to notify of the shipment, the number of samples in the shipment, the requested analyses, and the estimated time of arrival of the shipment.

APPENDIX D

Photographs

Containers for water samples


Water level sounder

Temperature, pH and conductivity meter

Flame cleaning of sampling port prior to sample collection

Field filtering of water samples to be analyzed for dissolved iron and manganese

Cleaning of sampling port

APPENDIX G

Wellhead Protection Plan

WELLHEAD PROTECTION PLAN

Limón de la Cerca, Honduras

June 2002

INTRODUCTION

The most effective means in protecting the groundwater quality used for public water supply in Limón de la Cerca is establishing a wellhead protection program. Wellhead protection is the practice of managing the land area around a well to prevent groundwater contamination. Prevention of groundwater contamination is essential to maintain a safe drinking water supply.

The control measures included in this section should be incorporated into municipal regulations to ensure control on water use and to protect the area covered with dense vegetation that represents potential groundwater recharge areas through rainfall infiltration.

Groundwater may become contaminated through natural sources or numerous types of human activities. One of the main causes of groundwater contamination induced by human activity is the effluent from septic tanks, cesspools, and latrines. Although each disposal system releases a relatively small amount of waste into the ground, the large number and widespread use of these systems results in a significant contamination source. Similarly, improper disposal of gray water, hazardous wastes, leaking fuel storage tanks, and chemical storage and spill sites are sources of contamination to groundwater.

KEY STEPS

Development of a wellhead protection plan for Limón de la Cerca consists of five key steps that are described in detail below:

Step 1: Planning. The municipality should assemble a team to arrive at a cooperative effort for wellhead protection objectives. The team may include municipal officials, representatives from the public works departments, environmental managers, and members from the local health department.

Team objectives should focus on delineation of a wellhead protection area to protect the water wells from unexpected contaminant releases, as well the development of a plan for controlling high-risk activities within the well recharge area.

Step 2: Delineate the Wellhead Protection Area. The geographic limits most critical to the protection of a well water supply must be delineated. Based on this information, a base map should be developed that shows detailed information on the natural features of the area, both surface and subsurface, land use including roadways and utilities, and location of all public supply wells and water recharge areas. Clear acetate overlays can be added that illustrate the radius of influence (even if estimated) for every pumping residential and municipal water supply well, location of aquifers and aquifer recharge zones, watershed in which the aquifers are located, wetlands, lakes and flood zones that may affect recharge, and potentiometric surface information that illustrates groundwater flow direction.

The actual delineation of a wellhead protection area ranges in complexity from drawing a circle of specified radius around each well, to more sophisticated techniques involving analytical methods and groundwater modeling. Using an arbitrary fixed radius - calculating a fixed radius measured from the well to the wellhead protection area boundary - is an inexpensive, easily implemented method of wellhead delineation. Choosing a large fixed radii will increase the protective effectiveness, but alternatively, could lead to overcompensation and unnecessary wellhead protection costs. However, a disadvantage of the fixed radius approach is that it is not based on hydrogeologic principles and could lead to inadequate protection of recharge areas. Given the limited aerial extent of the freshwater aquifer at Limón de la Cerca, the entire area may be included inside the protection zone.

Step 3: Identify and Locate Potential Sources of Contamination. The objective of this step is to prepare a master wellhead protection area map that shows all existing contaminant sources and identifies potential threats. First, a comprehensive inventory of potential and known contaminant sources should be developed within each wellhead protection area. Sources should include past and present waste sites such as sewage treatment and disposal areas, landfills, and chemical storage and disposal areas, including small commercial and any future industrial waste areas. The inventory should also include agricultural sources such as crops where pesticides and insecticides may have been used, animal feedlots, livestock waste disposal areas, and agricultural drainage ditches and canals. In addition, residential areas with septic systems, latrines, cesspools, and buried waste disposal areas should be inventoried. Once all of the potential sources of contamination have been identified, each source should be plotted on an overlay of the wellhead protection area.

Following identification of source areas, an evaluation of the immediacy and degree of risk associated with each potential source of contamination should be conducted. Values of risk can be assigned and ranked based on their proximity to groundwater supply, the nature of the contaminant, and the intended use of groundwater. By assigning risk values, it is possible to prepare a map illustrating the location and magnitude of potential threats to the groundwater supply, as well as aid in determining which areas require immediate attention to prevent contamination to the water supply.

Step 4: Manage the Wellhead Protection Area. A long term, low cost management wellhead protection plan can be tailored for the municipality. It may be initiated by addressing identified immediate threats to the groundwater supplies followed by a program of prevention and protection of future supplies. One easily achieved component of the plan is to institute a public education program to increase awareness of the threats of groundwater contamination and encourage groundwater protection and conservation measures. Other programs may include the municipality acquiring sensitive recharge areas and converting them to park land, recreational facilities, or other community-based land uses.

Another component of wellhead protection is groundwater monitoring. Regular groundwater monitoring around municipal and residential water supply wells can detect potential sources of contamination before they infiltrate the municipal water supply. A good groundwater monitoring program consists of collecting numerous groundwater samples on a regular basis and performing laboratory tests to detect various contaminants, which will identify problems quickly. The further the monitoring wells are located from the pumping well, the sooner problems can be identified and more time will be available to rectify the situation or provide adequate substitute water supplies.

Step 5: Plan for the Future. A critical component of a successful wellhead protection plan is regular annual review and update of the plan. This will allow for improvement of management strategies and provide time to act on new information regarding sources of contamination. A critical aspect of the plan is the identification of future hazards that could threaten the wellhead protection areas. Early identification will allow time to develop solutions or contingency plans for alternate water supplies.

APPENDIX H

Training and Workshops

TRAINING AND WORKSHOPS

Limón de la Cerca, Honduras

June 2002

INTRODUCTION

Brown and Caldwell conducted a series of workshops and training sessions throughout the project. These sessions consisted of project kick-off, status meetings, training sessions, and project wrap-up meetings, as described below.

Project Kick-off and Status Meetings

Initially, Brown and Caldwell held two project kick-off meetings to introduce the project to interested stakeholders and build consensus regarding project objectives. The kick-off meetings were held in Tegucigalpa on 3 May 2001 and in San Pedro Sula on 22 May 2001. Kick-off meeting agendas and lists of attendees are included at the end of this section.

On 11 July 2001, Brown and Caldwell held a workshop to present the conceptual hydrogeologic models we developed for each of the study areas and update interested parties on the status of the project. This meeting was held in San Pedro Sula. A workshop agenda and list of attendees is also included at the end of this section.

Training Sessions

To help ensure project sustainability, Brown and Caldwell held seminars to train local municipal personnel in groundwater monitoring techniques and in operating the water resource database developed for each project municipality. Groundwater monitoring training sessions were held on December 4th, 6th, and 10th, 2001 at Limon de la Cerca, the Sula Valley, and Utila, respectively. A training session agenda and list of municipal personnel who participated in the training is included at the end of this section. The training sessions on how to use and update the project databases developed by Brown and Caldwell were held in San Pero Sula and Tegucigalpa on February 12th and 14th, respectively. These training sessions were held at the local UNITEC campuses. Again, a training session agenda and list of attendees is included at the end of this section.

Project Wrap-Up Meetings

The project also calls for project wrap-up meetings to be held with mayors and other representatives of each municipality. These meetings are intended to help ensure project sustainability by introducing the project to the new municipal governments, discussing project results, and making recommendations for implementing components of the water resource management plans developed for each municipality. Although these meetings were not completed at the time of the writing of this report, the meetings were scheduled as follows:

Limon de la Cerca/Choluteca – 20 June 2002
Isla de Utila – 22 June 2002
Choloma – 24 June 2002
La Lima – 25 June 2002
Villanueva – 26 June 2002.

A copy of the agenda for the wrap-up meetings is included at the end of this section.

PROJECT KICK-OFF AND STATUS MEETINGS

AGENDA
May 3, 2001 Kickoff Meeting – Tegucigalpa
USAID Groundwater Monitoring (Water Resource Management) Studies
Choloma, La Lima, Limón de la Cerca, Utila, Villanueva

I. Introduction
- A. USAID Project Background (audience introductions)
- B. Brown and Caldwell Project Team

II. Project Goals and Objectives – Jeff Nelson
- A. Background
- B. Meeting Objectives (consensus)
- C. Project Objectives (sustainability)
- D. Scope of Work/5 Phases
- E. Municipality Needs

III. Program Implementation – Horacio Juarez
- A. Development of Partnerships
- B. Sustainability
- C. Project Schedule

10:30 – 10:45 Coffee Break

IV. Project Overview – Jim Oliver
- A. Conceptual Model
- B. Hydrogeology
- C. Modeling
- D. Matrix Prioritization

V. Water Resource Management Plans – Paul Selsky
- A. Water Needs
- B. Water Supply and Delivery
- C. Recommendations
- D. Management Plan Development

12:00 – 1:30 Lunch Break

VI. Municipality Input – Audience

VII. Technical Approach – Jay Lucas/Milton Sagustume
- A. Phases (update)
- B. Drilling
- C. Project Schedule

3:00 – 3:15 Coffee Break

VIII. Data Base – Allan Scott
- A. USGS Data Base
- B. Project GIS
- C. Technology Transfer and Training

IX. ReCap and Open Discussion
- A. Consensus

5/3/2001

Name	Organization	Phone Number
ALLAN SCOTT	BROWN & CALDWELL	916 853-5380
Barbara Goodrich	Brown & Caldwell	925-210-2345
Francisco Casco	Municipalidad Villanueva	504-670-[illegible]
Ramón Jiménez Flores	Municipalidad Villanueva	670-44-45
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Carlos M. Flores	USAID	236-9320-X-44[illegible]
Paul Selsky	Brown & Caldwell	
Alicia Villar Landa	PRIMHOR	239-41-14/41-8[illegible]
Maurice James	U.S. Army Corps of Engineers	991-9189
Mauricio Cruz	USAID	236-9320 (479[illegible]
Carlos Verdial	USAID	236-9320 (40[illegible]
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Olman O. Rivera	USACE-USAID	995.74-79
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Ricardo Valle L	FUNDEMUN.	985 4930
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Name	Organization	Phone Number
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Lisa Pacholek	CHF	LPacholek_CHF@cablecolor.hn
Karen Perez	Brown & Caldwell	983-1604

AGENDA
22 de Mayo 2001
Estudio y Monitoreo de Aguas Subterráneas (Manejo de Recursos de Agua)
Los Municipios de Choloma, La Lima, Limón de la Cerca, Utila, Villanueva
Financiado por USAID

I. Introducción – Ing. Carlos Flores
   A. Antecedentes del Proyecto USAID (Presentación de los Participantes)
   B. Presentación de Brown and Caldwell y el equipo técnico del Proyecto

II. Metas y Propósitos del Proyecto – Ing. Jeff Nelson
   A. Antecedentes
   B. Propósitos de la Reunión (consenso)
   C. Propósitos del Proyecto (sostenibilidad)
   D. Alcance del Trabajo (cinco fases)

III. Implementación del Programa – Ing. Horacio Juarez
   A. Desarrollo de Asociaciones entre Agencias Participantes
   B. Sostenibilidad
   C. Programa del Proyecto

IV. FUNDEMUN – Ing. Jenny Chávez
   Aplicación de Tasas de Cobre por Explitación de Aguas Subterráneas según Plan de Arbitrios

   DESCANSO (Quince minutos)

V. Resumen de Actividades del Proyecto
   A. Evaluación de Sistemas Existentes y Recopilación de Datos – Ing. Dean Wolcott
   B. Base de Datos Hidrogeológicos – Lic. Dean Wolcott
   C. Modelación Hidrogeológica – Ing. Milton Sagastume
   D. Manejo de Recuros Hídricos – Ing. Milton Sagastume
   E. Programa de Perforación de Pozos – Ing. Milton Sagastume

VI. Comentarios por parte de Alcaldes, Gerentes o Jefes de Servicios

US AGENCY FOR INTERNATIONAL DEVELOPMENT
USAID/Honduras

Tegucigalpa, M.D.C.
21 de mayo de 2001

A QUIEN INTERESE

De todos es conocido, que cada vez es más frecuente y significativa la utilización y explotación de acuíferos subterráneos para satisfacer las demandas de agua de las poblaciones de varias comunidades y ciudades alrededor del país. Por lo que es fácilmente previsible que el uso de las aguas subterráneas para el abastecimiento de agua potable en estas localidades, se incrementará en la misma medida que haya un crecimiento de la población futura y por lo tanto los rendimientos de estos acuíferos se verán disminuidos en una mayor proporción.

Los sistemas de abastecimiento de agua de las ciudades de La Lima, Choloma y Villanueva en el valle de sula, de la Isla de Utila y de Choluteca, que utilizan las aguas subterráneas como principal fuente de abastecimiento, fueron severamente dañados durante el paso del Huracán Mitch. Actualmente, la Agencia Internacional para el Desarrollo de los Estados Unidos (USAID) realiza fuertes inversiones en estas regiones para construir nuevos centros habitacionales y para rehabilitar y a su vez expandir los sistemas de abastecimiento de agua respectivos.

Recientemente, la USAID ha contratado los servicios de la Firma Consultora Brown and Caldwell para elaborar un estudio de monitoreo de aguas subterráneas en las ciudades arriba mencionadas. El desarrollo de dicho proyecto conlleva el realizar estudios hidrogeológicos, recopilar una base de datos que provea información suficiente para implementar planes prácticos y efectivos en la administración del recurso agua subterránea en cada localidad y determinar si este recurso cumple y satisface adecuadamente las expectativas y requerimientos de demanda actual y futura. Así mismo, el Estudio contempla realizar una evaluación preliminar de la infraestructura de abastecimiento de agua subterránea existente en cada municipalidad y desarrollar costos estimados preliminares para el mejoramiento de esta infraestructura.

El éxito de este proyecto será medido al asegurar la sostenibilidad de los objetivos planteados en el mismo, una vez que éste finalice. Por lo tanto, un componente fundamental para asegurar dicha sostenibilidad será el de crear relaciones de trabajo permanentes entre el Consultor y cada una de las municipalidades involucradas, así como con otros organismos y/o instituciones relacionadas con el tema de aguas subterráneas, como ser SANAA, FUNDEMUN, Acción Contra el Hambre, UNITEC y la Comisión Ejecutiva del Valle de Sula. Dentro de este contexto, cabe mencionar que es menester de la Municipalidad designar el recurso humano necesario para que sea debidamente

Mailing Addresses: From USA: USAID/Honduras, UNIT 2927, APO AA 34022. Tel. 011-504-236-9320
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capacitado por la Firma Consultora en el manejo, seguimiento y monitoreo del modelo y de la base de datos que será proporcionada a la Municipalidad.

En base a lo anterior, solicitamos su gentil cooperación para proporcionar toda aquella información que usted estime conveniente a la Firma Brown & Caldwell, la cual ha sido contratada para elabora este estudio. Su cooperación y asistencia son vitales para alcanzar el éxito y garantizar los futuros recursos de agua subterránea en Honduras.

Atentamente,

Todd Sloan
Director
Oficina de Desarrollo Municipal
e iniciativas Democráticas

Lista de Invitados

22 de Mayo 2001

optinet. hn.

USAID

BROWN AND CALDWELL

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5	José Francisco Casco	Municipalidad Villanueva	226-7269	670-04-47
6	Ramon Jiménez Flores	Municip. de Villanueva	670-04-47	
7	Hector A Cabrera	MUNIC. de Villanueva	6704084	
8	Javier Reyes	MUNIC. de Villanueva	690-4445	
9	Rigoberto Rivera C	Municip. de Villanueva	670-58-80	
10	Ruben - Saravia	Municip. de Lima	668.29.00	
11	Dilcia Fernandez	Alcaldía La Lima	991.6547	DIF zelaya @
12	Monterey Cárdenas	Municipalidad de Utila	425-3293	—
13	Juan Ramón Mejía A.	Municipalidad Choloma	669.39.22	— " —
14	Deuo Ordaimo	Municipalidad de Choloma	669 5372	
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30	Darwin A. Vallecillo	ATICA	566-0701	[illegible]@[illegible]ach.com
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34	Nely R. Lemus	ATICA	558-1751	— o —
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36	José Evaristo Ecija F.	Municipalidad La Lima	668-26-01	
37	Doris Marlene Pérez Lagos	Municipalidad La Lima	668-26-01	
38	Mario Ramón Jiménez Soto		6512735	

Lista de Invitados

22 de Mayo 2001

USAID

BROWN AND CALDWELL

No.	Nombre	Empresa/Corporación	Teléfono	E-mail
	German Wilfredo Henriquez	Municipalidad Lima	6682480	

AGENDA
USAID Monitorio y Estudios de Aguas Subterráneas
Presentación del Modelo Conceptual Hidrogeológico Preliminar
Utila, Valle de Sula y Limón de la Cerca

11 de Julio 2001
9:30 a.m.
Hotel Princess
San Pedro Sula

I. INTRODUCCION

II. RECURSOS DE AGUA EXISTENTES
   A. Fuentes de Agua
   B. Localización de Pozos

III. MODELOS CONCEPTUALES HIDROGEOLOGICS PRELIMINARES
   A. Geología
   B. Hidrogeología

IV. DATOS
   A. Geología
   B. Hidrogeología
   C. Calidad de Agua
   D. Modelación
   E. Información del Sistema de Agua

V. FASE II INVESTIGACION DE CAMPO
   A. PERFORACION
      1. Pozos de Prueba
      2. Aquíferos de Prueba
      3. Muestreo y Análisis de Agua

   B. ESTUDIOS GEOFISICOS
      1. Estudios EM
      2. Estudios Sísmicos y Reflexión

VI. EVALUACION DE LA INFRAESTRUCTURA DEL SISTEMA DE AGUA
   F. Población
   G. Uso de Agua
   H. Facilidades de Sistema de Agua

VII. DISCUSION

11 de Julio 2001
Invitee List

VILLANUEVA MUNICIPALITY 670-4788/670-4445

1. Lic. José Felipe Borjas (Alcalde Municipal)
2. Lic. Francisco Casco (Jefe de Obras y Servicios Públicos)
3. Lic. Rigoberto Rivera (Jefe de Servicios Públicos)
4. Juan Pago Avila (Jefe de Departamento de Agua)
5. Alfredo Cabrera (Jefe de Operación de Mantenimiento)
6. Ramón Jímenez Flores
7. Hector Cabrera

LA LIMA MUNICIPALITY 668-2400/668-2601

1. Lic. Evaristo Euceda (Alcalde Municipal)
2. Ing. Doris Pérez (Directora de Servicios Públicos)
3. Ruben Saravia (Jefe de Servicios Públicos)
4. Ing. Aurora Rodríguez (Asistente)
5. Jorge Nery López (Asistente Departamento de Catastro)
6. Dilcia Fernandez
7. Lic. José Luis Caballero-- ASITENCIA SOLICITADA POR ALCADE
8. Ing. German Henríquez-- ASITENCIA SOLICITADA POR ALCADE

CHOLOMA MUNICIPALITY 669-3322/6693223

1. Lic. Armando Gale (Alcalde Municipal) (no)
2. Ing. Osman Alvarenga (Director de Servicios Públicos)
3. Ing. Julio César Hernández (Jefe de Servicios Públicos)
4. Ing. Edy Martínez (Asistente de Ingeniería)
5. Juan Ramón Mejía
6. Dario Perdomo

LIMON DE LA CERCA 882-5079/ 882-5011

1. Actilio Alvarez (Técnico DIMUSED)
2. Manuel Mejía (Técnico DIMUSED) (no)
3. Juan Benito Guevara (Alcalde Municipal) (no)

FUNDEMUN

1. Ing. Mario Alberto Garcia
2. Ing. Jenny Chávez (Choloma, Villanueva) 984-1577
3. Ing. Jose Tulio Gómez (La Lima) 647-3136

COE

1. Rueben Rosales

UTILA MUNINICIPALITY 425-3255

1. Monterrey Cárdenas (Alcalde Municipal)

UNITEC

11 de Julio 2001
Invitee List (Continued)

AGUAS DE SAN PEDRO

1. Ing. Claudia Enamorado

SANAA

1. Rodolfo Ochoa (Arturo Trochez en representación) (220-6506)

USAID (236-9320)

1. Carlos Verdial
2. Mauricio Cruz
3. Frank Almaguer (Embajador)
4. John Jones (Consul)
5. Timothy M. Mahoney (Director de la Misión)
6. Glenn Berce-Oroz (Director Interino de la oficna de Desarrollo Municipal e Iniciativa Democrática)
7. Charles Oberbeck

PRIMHOR (239-4114)

1. Alicia Villar Landa (Ing. Victor Manuel Leva Coordinador unidad SPS)

USGS (236-7776

1. John Walkey
2. Olman O. Rivera
3. Jeff Phillips

FHIS

1. Jorge Flores (992-6334)
2. Antonio Morales (980-2090)
3. Gunther Von-Weise
4. Ing. Samuel Alvarado

USAGE

1. Carlos Selva

CHF

1. Lourdes Retes (Asistirá *Nohemy Carrasco* de parte de HOGAR)
2. Lisa Pacholek (no asistirá)

LISTA ASISTENTES

11 de Julio 2001

HOTEL PRINCESS, SAN PEDRO SULA

NOMBRE	EMPRESA	CARGO	TELEFONO	FAX	E-MAIL	FIRMA
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orge Nery Lopez	Munic-La Lima	Asistente-Catastro	668-24-00			
Ramón Jiménez Flores	Munic. de Villanueva	Obras Publicas	670-44-45	670-44-04		
Victor M. Leva	PRIMHUR	Gerente Regional	550-40-06	550-40-06		
Noemi Carrasco	CHF	Oficial Tecnico	2325758	idem		
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Marlon Pineda	Africa	Supervisor	558-17-51	558-18-0[illegible]		
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LISTA ASISTENTES

11 de Julio 2001

HOTEL PRINCESS, SAN PEDRO SULA

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Alton Cooper	Alton's Dive Center	Owner/Dueño	425-3337	425-3108	altons@hondutel.hn	
[illegible] O. Alvarenga	Munic. Choloma	Jefe Obras y Serv.	669-3223	669-1774	calvarenga[illegible]@hotmail.com	
[illegible] Francisco Carcamo	Municip. Villanueva	Gerente Obras y Ser	P. 670-4445	670-4404		
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Jorge Nery Lopez	Municipalidad La Lima	Asist. - Dept. Catastro	668-24-00	668-26-01		
Ruben Samayoa	Municipalidad Lima	Jefe-Serv-Pub.	668-24-00	668-26-01		
Julio César Hernández	Municipalidad Choloma	Asesor Tecnico	669-32-23	669-17-74	—	
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TRAINING SESSIONS

GROUNDWATER MONITORING STUDIES/HONDURAS
GROUNDWATER MONITORING TRAINING
December 4, 6, and 10, 2001

INTRODUCTION

Brown and Caldwell performed three groundwater monitoring training events in early December, 2001, covering the five project municipalities. Similar training was conducted throughout Phase II of the project and the purpose of the recent training was to reinforce knowledge and practices learned by the participants during earlier fieldwork and training. Attached is the outline that was presented for the training session.

The training of Honduran personnel is essential to one of the project's main goals: project sustainability. The purpose of the training program is to ensure that each municipality will continue the Groundwater Level and Monitoring Program after the current project is completed.

These training sessions were conducted by Dean Wolcott, P.G., with the assistance of Barbara Goodrich and Fabiola Andrade (Sula Valley and Utila). Mr. Atilio Alvarez, technician for the municipality of Choluteca, assisted the BC staff in the Limon de la Cerca/Choluteca training session.

TRAINING PARTICIPANTS

The following lists describe the individuals who participated in the groundwater monitoring training. While the majority of participants are municipal engineers and technicians, personnel from non-governmental organizations were also invited and participated.

Site: Limon de la Cerca / Choluteca
Conducted by: Dean Wolcott, P.G., and Atilio Alvarez
Training date: December 4, 2001

PARTICIPANT	ORGANIZATION
Romulo Vivas	DIMUSEB/Choluteca
Guillermo Ordonez	DIMUSEB/Choluteca
Atilio B. Alvarez	DIMUSEB/Choluteca
Rosa Fiallos	PNUD/DIMUSEB
Cesar H. Mondragon	FUNDEMUN
Jorge Flores	FHIS

Site: La Lima, Villanueva, and Choloma
Conducted by: Dean Wolcott, P.G., Barbara Goodrich, and Fabiola Andrade
Training date: December 6, 2001

PARTICIPANT	ORGANIZATION
Jorge Nery Lopez Vasquez	La Lima Municipality
Jose Ruben Saravia	La Lima Municipality
Doris Marlenee Perez Lazo	La Lima Municipality
Alexis Orellana Martinez	La Lima Municipality
Jenny Mariela Chavez	FUNDEMUN
Jose Rigobero Rivera	Villanueva Municipality
Julio Cesar Hernandez	Choloma Municipality
Osman O. Alvarenga. M.	Choloma Municipality
Carlos R. Castillo L.	Choloma Municipality
Jose Francisco Casco P.	Villanueva Municipality
Hector A. Cabrera	Villanueva Municipality
Olga Lara de Hubin	Choloma Municipality
Antonio Morales Flores	FHIS

Site: Island of Utila
Conducted by: Dean Wolcott, P.G., Barbara Goodrich, and Fabiola Andrade
Training Date: December 10, 2001

PARTICIPANT	ORGANIZATION
Jonell Jackson	
Joslyn J. Ponce	
Alton Cooper	Utila (Mayor Elect)
Glenn Gabourel	Island Spring
Jorge Flores	FHIS
Gilda Ordonez	Utila
Carolina Escobar	Utila

TRAINING TOPICS

The subject matter of the training sessions consisted of all relevant technical material associated with the Groundwater Level and Monitoring Program. Topics included monitoring system well selection criteria, groundwater level measuring methodology, groundwater sampling methodology, field analysis of groundwater samples, laboratory analysis of groundwater samples, quality assurance/quality control, and data interpretation.

Each training session consisted of a classroom lecture and discussion followed by a hands-on field practice session where monitoring and data collection activities were conducted at a monitoring well.

A special emphasis was placed on proper documentation of field activities and the use of designated data collection forms developed for the Program.

TRAINING MATERIALS

Training participants were provided with a copy of the Groundwater Level and Monitoring Program Field Manual. This field manual contains detailed descriptions of the activities contained in the monitoring program, copies of field data forms, pictures of specific field activities, and a list of wells in the monitoring well network for each municipality.

Materials provided in the training sessions included an electronic water level meter, Oakton field water quality kit, groundwater sample kit, water filter apparatus, and other monitoring equipment.

Water Resources Management System
Training Summary
February 12 and 14, 2002

Introduction

Brown and Caldwell conducted two training workshops in February to train representatives from each municipality on the use of the Water Resources Management System (WRMS). The WRMS is a custom database and geographic information system application that has been custom developed to use as a water resource planning tool to support the goals of this project.

Integration of the use of the WRMS with the other recommendations and programs established in this project are essential to the main project goal of providing for sustainable water resource management in the future. The WRMS has been designed to support other project programs such as the Groundwater Level and Monitoring Program (training conducted in December, 2001). The purpose of this training was to provide hands-on training and experience with the WRMS application so that the municipalities can use it to maintain and manage data and to use the tool for future decision-making.

The main goals of the training were to gain an understanding of the capabilities of the WRMS, learn how to enter and manage data, and create maps and reports from data in the database. Each workshop consisted of a one-day hands-on course and covered a system overview, how to start using the system, entering infrastructure data, accessing other resources, system administration, creating GIS basemaps, and using well prioritization tools. The following workshops were conducted:

- UNITEC Campus, San Pedro Sula, February 12, 2002;
- UNITEC Campus, Tegucigalpa, February 14, 2002.

Training Topics

Each workshop was conducted at the UNITEC computer laboratory and each participant had their own computer and a training copy of the database. The participants used a 114 page training manual that contained a detailed discussion of each function in the WRMS, theory and recommendations for best practices, and 20 individual exercises designed to provide hands-on training and practice. During the training, the following objectives were successfully accomplished by the participants:

- Learn the components of the WRMS
- Enter and edit service areas data
- Enter well information
- Store images and other electronic files
- Enter water quality samples and water levels
- Enter storage tank information
- Create reports from the database

- Learn how to access other resources (the USGS Groundwater Well Database, Municipal Water Resources Reports, etc.)
- View wells and storage tanks on a map
- Use the basic functionality of ArcView to create a map
- Display well information on a map (water level, water quality, depth, etc.)
- Overview of the well site prioritization tool

Training Participants

Training was conducted by Allan Scott of Brown and Caldwell, with assistance from Fanny Letona (ATICA), David Esponiza (ATICA), and Fabiola Andrade (Brown and Caldwell).

The following are lists of the individuals that participated in the workshops.

San Pedro Sula, February 12, 2002 participants:

Participant	Organization
Ramón Jimenéz Florez	Villanueva Municipality
José Rigobero Rivera	Villanueva Municipality
Francisco Casco	Villanueva Municipality
Marvin Pinador	Villanueva Municipality
Jackeline Reyes	La Lima Municipality
Jose Ruben Saravia	La Lima Municipality
Carlos H. Ochoa	La Lima Municipality
Doris Perez	La Lima Municipality
Julio Cesar Hernández	Choloma Municipality
Ruglio Diaz	UNITEC

Tegucigalpa, February 14, 2002 participants:

Participant	Organization
Mauricio Cruz	USAID
Carlos Verdial	USAID
Jorge Flores	FHIS
Glenn Gabourel	Utila Municipality
John Walkey	USGS

PROJECT WRAP-UP MEETINGS

USAID Groundwater Water Resources Management Project
Project Wrap-up Workshop Agenda

Introductions (All)

Project Purpose (USAID)
- History
- Objectives

Project Sequence (BC/Atica)
- Initial data gathering
- Conceptual model development
- Field Investigation
- Groundwater flow model
- Evaluation

Results and Findings (BC/Atica)
- Water requirements/demand
- Aquifer characteristics
- Groundwater quality
- Future wells
- Well head protection

Data base (BC/Atica)

Training (BC/Atica)

Computers & Equipment (USAID)

Recommendations/Summary

Break

Field visit to wells